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AN EVALUATION OF FULL-SCALE FABRIC FILTERS ON UTILITY BOILERS: PP&L BRUNNER ISLAND STATION UNIT 1

by

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16. ABSTRACT The report gives results of two series of total mass and fractional size particulate emission tests at Pennsylvania Power and Light's Brunner Island Station Unit 1 on August 12-16, 1981, and September 2-4, 1982, as part of a program to evaluate and characterize the performance of full-scale fabric filter units installed on 100 MW or larger coal-fired power plants. The fabric filter is a reverse-air unit with 24 compartments. Each compartment has 264 bags, 34 ft 4 in. long and 11.5 in. in diameter. Design air/cloth ratio is 1.8. Outlet emissions for the 1981 tests averaged 0.037 lb/million Btu, with an average efficiency of 99.7%. Outlet emissions for the 1982 tests averaged 0.096 lb/million Btu, with an average efficiency of 98.4%. Mean particle sizes were 13.4 micrometers at the inlet and 7.0 micrometers at the outlet in 1981, and 19.9 micrometers at the inlet and 9.0 micrometers at the outlet in 1982. For 2 years, beginning at start-up of the fabric filter, strip charts and daily operation and maintenance records were reviewed and key data recorded. A discussion of bag life and pressure drop problems and attempted solutions is included.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Combustion	Pollution Control	13B	21B
Filtration	Particles	Stationary Sources	07D	14G
Fabrics		Fabric Filters	11E	
Utilities		Particulate		
Boilers			13A	
Coal			21D	

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Abstract

The overall objective of this program was to evaluate and characterize the performance of full-scale fabric filter units installed on 100 MW or larger coal-fired power plants. This document reports on two occasions of particulate emission testing separated by approximately a one year period and operation and maintenance data reviewed for the period from baghouse startup through the second emission test series. A separate report documents a similar emission test series at a second location.

A series of tests conducted at Pennsylvania Power and Light's Brunner Island Station, Unit 1 on August 12-16, 1981, and again on September 2-4, 1982. A total of five (5) inlet-outlet tests were conducted in August, 1981, and three (3) inlet-outlet tests were conducted in September, 1982.

Emissions for Unit 1 are controlled by a twenty-four (24) compartment Carborundum baghouse. The gas flow through the baghouse is 1,200,000 ACFM at 300°F. Each compartment contains 264 bags, each bag measuring 11.5 inches in diameter and 35 feet, 4 inches in length.

Outlet emissions for the August 1981 tests averaged 0.037 lbs/10^6 Btu, with an average baghouse efficiency of 99.7%. Average outlet emissions for the September 1982 test were 0.096 lbs/10^6 Btu and the average baghouse efficiency was 98.4%. The allowable particulate emission rate for this source stipulated by the Pennsylvania Department of Environmental Resources is 0.10 lbs/10^6 Btu.

Two (2) inlet-outlet and two (2) blank Cascade Impactor tests were performed during the August, 1981 program. The impactor test series of September, 1982 included ten (10) runs: four inlet runs, four outlet runs and two blanks. Mean particle sizes were found to be 13.4 um at the inlet and 7.0 um at the outlet during the August, 1981, tests and 19.9 µm at the inlet and 9.0 µm at the outlet during the September, 1982 tests.

Beginning with baghouse startup and covering a period through September 1982, strip charts and daily operation and maintenance records were reviewed and key data recorded. A discussion of bag life and pressure drop problems and attempted solutions is included. Results of laboratory analysis of the bags are also provided.

ACKNOWLEDGEMENTS

Great appreciation is expressed to Dale Harmon, EPA Project Officer, for his guidance and contribution to this test program. The cooperation of John Hampson, Greg Lear and Greg Schmidt of Pennslyvania Power and Light made this program possible.

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LIST OF ABBREVIATIONS AND SYMBOLS

1. Btu - British thermal units
2. °F - Degrees Farenheit
3. ACFM - Actual Cubic Feet per Minute
4. Oz - Ounce
5. lb/hr - Pounds per Hour
6. μ - Micrometer
7. ml - Milliliters
8. CFM - Cubic Feet per Minute
9. lbs/10^6 Btu - Pounds per Million Btu
10. DSCFM - Dry Standard Cubic Feet per Minute
11. gr/ACF - Grains per Actual Cubic Feet
12. DSCF/10^6 Btu - Dry Standard Cubic Feet per Million Btu
13. SO_2 - Sulfur Dioxide
14. O_2 - Oxygen
15. NO_x - Nitrogen Oxide
16. CO - Carbon Monoxide
17. VWC - Vertical Water Column
18. Fill - Crosswise threads woven by loom. Yarn running from selvage to selvage at right angles to the warps in woven fabrics.
19. Warp - The yarn running lengthwise (machine direction) in a woven fabric.

CONVERSION FACTORS FOR BRITISH AND METRIC UNITS

To convert from	To	Multiply by	To	Multiply by
^oF	^oC	$\frac{5}{9}$ $(^oF-32)$	---	---
ft.	meters	0.305	centimeters	30.5
ft.^{2}	meters^2	0.0929	centimeters^2	929.0
ft.^{3}	meters^3	0.0283	centimeters^3	28,300.0
ft./min. (fpm)	centimeters/sec.	0.508	meters/sec.	5.08×10^{-3}
ft.^{3}/min.	centimeters^3/sec.	471.9	meters^3/hr.	1.70
in.	centimeters	2.54	meters	2.54×10^{-2}
in.^{2}	centimeters^2	6.45	meters^2	6.45×10^{-4}
oz.	grams	28.34	grains	438.0
oz./yd.^{2}	grams/meter^2	33.89	grams/centimeter^2	3.39×10^{-3}
grains	grams	0.0647	---	---
grains/ft.^{2}	grams/meter^2	0.698	---	---
grains/ft.^{3}	grams/meter^3	2.288	---	---
lb. force	dynes	4.44×10^5	Newtons	0.44
lb. mass	kilograms	0.454	grams	454.0
lb./ft.^{2}	grams/centimeter^2	0.488	grams/meter^2	4880.0
in. H_2O/ft./min.	cm. H_2O/cm/sec.	5.00	Newtons/meter^2/cm/sec.	490.0
Btu	calories	252	---	---

I. INTRODUCTION

This is the final report for EPA Contract No. 68-02-3649 entitled An Evaluation of Full-Scale Fabric Filters on Utility Boilers. This research was conducted from November, 1980 to October, 1983, by ETS, Inc. under the direction of U. S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Office of Research and Development.

The original intent of this program was to select, and later evaluate and characterize the performance of three (3) full-scale fabric filter units installed on 100 MW or larger coal-fired power plants.

This objective soon proved to be a formidable task due to the time required to gain permission to perform emission tests for the Environmental Protection Agency, as well as the complexity of the available test sites.

As a result, tests were performed at only two utilities: Pennsylvania Power and Light's - Brunner Island, Unit 1 and Southwestern Public Service - Harrington Station, Unit 3. One series of tests was performed at the SPS Harrington Station and two series of tests were performed at the PP&L Brunner Island Station. Emphasis was placed on selecting utilities that were representative of different boilers and coal types, and that have installed fabric filter control systems using modern design features.

Total mass and fractional size efficiency testing for particulate matter were performed. Efforts were also made to monitor and document operations, maintenance, and performance, along with cost and operating problem data.

Mass particulate removal performance for each fabric filter system was measured incorporating the methods described in the Federal Register (Methods 1-5). Assembly and use of the impactor train followed state-of-the-art protocol and general Method 5 sampling train procedures. At least three (3) inlet and outlet particulate tests were conducted at each site.

In addition to the two detailed test programs conducted at the PP&L Bruner Island Station, detailed operational and maintenance data were recorded over a two year period beginning with unit startup, October 19, 1980 through September 31, 1982. These data have been analyzed exhaustively and the results and recommendations of this work appear in this report.

This report covers the two test series and the O&M data obtained at the PP&L Brunner Island Station. A separate report covers the work done at Southwestern Public Service Harrington Station 3.(1)

II. CONCLUSION

Average outlet concentrations for both test series were higher than expected. Outlet emissions for the August, 1981 tests averaged 0.037 lbs/10^6 Btu, while the average baghouse efficiency was 99.7%.

Average outlet emissions for the September, 1982 tests were 0.096 lbs/10^6 Btu while the average baghouse efficiency was 98.4%. The allowable particulate emission rate for this source, stipulated by the Pennslvania Department of Environmental Resources, is 0.10 lbs/10^6 Btu.

Two (2) inlet-outlet and two (2) blank Cascade Impactor tests were performed during the August, 1981 program. The impactor test series of September, 1982 included ten (10) runs: four inlet runs, four outlet runs and two blanks. Average mass mean diameter were found to be 13.4 µm at the inlet and 7.0 µm at the outlet during the August, 1981 tests and 19.9 µm at the inlet and 9.0 µm at the outlet during the September, 1982 tests.

Maintenance problems at Brunner Island, Unit 1 have centered around very poor bag life. The most significant operating problem encountered was that of rising pressure drop across the baghouse.

An overview of laboratory tests on the used bags indicates that while the burst and tensile strength are no indication of potential problem, the flex results do raise a flag and indicate a large percentage of strength has been lost. Any further deterioration in flex strength would be a cause for alarm and possibly be an indicator of numerous potential bag failures. The permeability values of the bags "as received" are not considered unusual for bags that have been used in baghouses installed on coal-fired boilers. However, the recovery of the permeability after 30" vacuum is poor and may be an indicator of the cause of increased pressure drop because of dust being lodged in the fabric interstices. It is very difficult to remove this dust using conventional cleaning techniques.

III. DESCRIPTION OF PP&L BRUNNER ISLAND UNIT 1

The Brunner Island Boiler No. 1 operates at 350 MW and 2,200,000 lb. steam/hour. Boiler design pressure is 2,750 psi with operating conditions of 2,500 psig and 1005°F at the superheater. Reheater design is 600 psig with an outlet steam temperature of 1005°F. (2)(3)(4)

Boiler No. 1 is a tangentially fired Combustion Engineering boiler with controlled circulation, pulverized bituminous firing, furnace and reheat.

Five Combustion Engineering Raymond bowl mills, each rated at a nominal capacity of 61,400 lbs/hr, supply the boiler with fuel. The boiler is initially fired using No. 2 fuel oil. Oil firing can also be used to supplement coal-firing at any boiler load. The oil firing system consists of 48 ignitors, each rated at 5 gallons per hour, with 8 main oil guns, four of which are rated at 200 gallons an hour, and four rated at 325 gallons per hour.

The following are flue gas conditions for Brunner Island - Unit 1:

(1) Inlet dust load - 0 - 7.0 grains/acf

(2) Maximum flue gas volume - 1,200,000 cfm

(3) Maximum flue gas temperature - 500°F

(4) Normal flue gas operating temperature - 330°F

(5) Raw coal analysis - 1.1 to 3.0% sulfur (dry basis).

The flue gas from boiler No. 1 is directed into a common stack that is shared with unit No. 2. Two induced-draft fans are installed on each unit. The I.D. fans for unit No. 1 were modified by PP&L to accommodate the baghouse.

Particulate emissions from unit No. 1 were initially controlled by two parallel electrostatic precipitators. The original precipitator was manufactured by Research Cottrell and the second precipitator was built by Buell (Ref: Figure 1).

Since the only space available to construct a full-scale baghouse was located west of the stack, extensive duct work runs and modifications were required. The Buell precipitator was blanked off and retired in place and all of the gas flow was directed through the original Research Cottrell precipitator. Only the perforated plates were removed from the R.C. precipitator. The ash handling system of this de-energized precipitator is still used to remove any dust that settles into the hoppers. Figure 2 depicts the baghouse and associated duct work arrangement in relation to the original control equipment and duct work.

The unit No. 1 baghouse was designed, furnished, delivered and erected by the Carborundum Company (Environmental Systems). Basic design is as follows:

Basic Design:

Number of compartments - 24

Number of bags per compartment - 264

Total number of bags - 6,336

Bag diameter - 11-1/2"

Center to center bag spacing - 14" with 3 bag reach

Bag length - 35'4"

Effective cloth area/bag - 103.3 sq. ft.

Total area (sq. ft. per compartment) - 27,271

Total area (sq. ft. for baghouse) - 654,508

Reverse air volume - 41,000 acfm

Air-to-cloth ratios:

(a) Gross air-to-cloth ratio (without reverse air flow) - 1.83:1

(b) Net air-to-cloth ratio with reverse air flow and 2 compartments out for cleaning - 2.13:1

(c) Net air-to-cloth ratio with reverse air flow and 4 compartments out of service - 2.3:1.

Original filter bags were manufactured by the Filter Media Division of the Carborundum Company. The majority of the bags were 9.8 oz. fiberglass with Teflon "B" finish. Two hundred test bags with "acid resistant" coating were installed in one compartment.

Bag dimensions and description were as follows:

Diameter - 11-1/2"

Bag length - 35'-4"

Weight (oz/sq. yd) - 9.8

Weave - 3 X 1 twill

Permeability (cfm per sq. ft.) - 40 to 50 cfm

Top suspension method - chain, compression spring and disposable cap

Bottom retainment - compression band sewn into bottom of each bag. The bag is angled to fit the lower part of the band into a recessed groove near the top of the thimble. The upper part of the band slips over the top of the thimble. The bag is then pulled up vertically to seal on the tapered bead at the top of the thimble. No clamps or tools are required to install a bag on a thimble. Anti-collapsing filter bag rings are 3/16" dia. cadmium plated steel rings, quantity 8 per bag. Tension - tension is varied by chain and clip at the top of the bag. Tension is measured by spring deflection. Initial bag tension was set at 75 pounds.

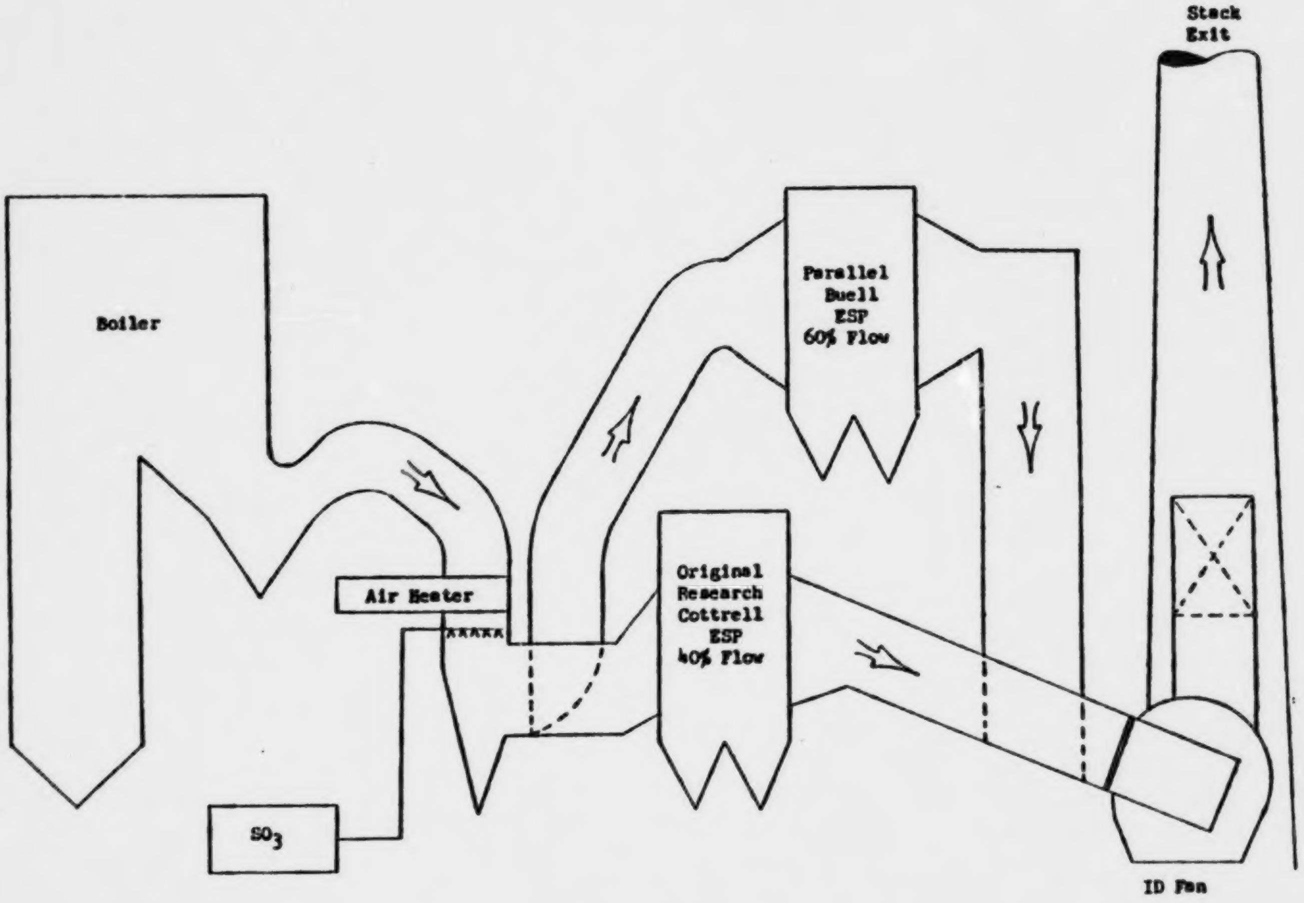

Stack
Exit
Boiler
Parallel
Buell
ESP
60% Flow
Air Heater
Original
Research
Cottrell
ESP
40% Flow
SO3
ID Fan

Figure 1. Original Equipment Arrangement

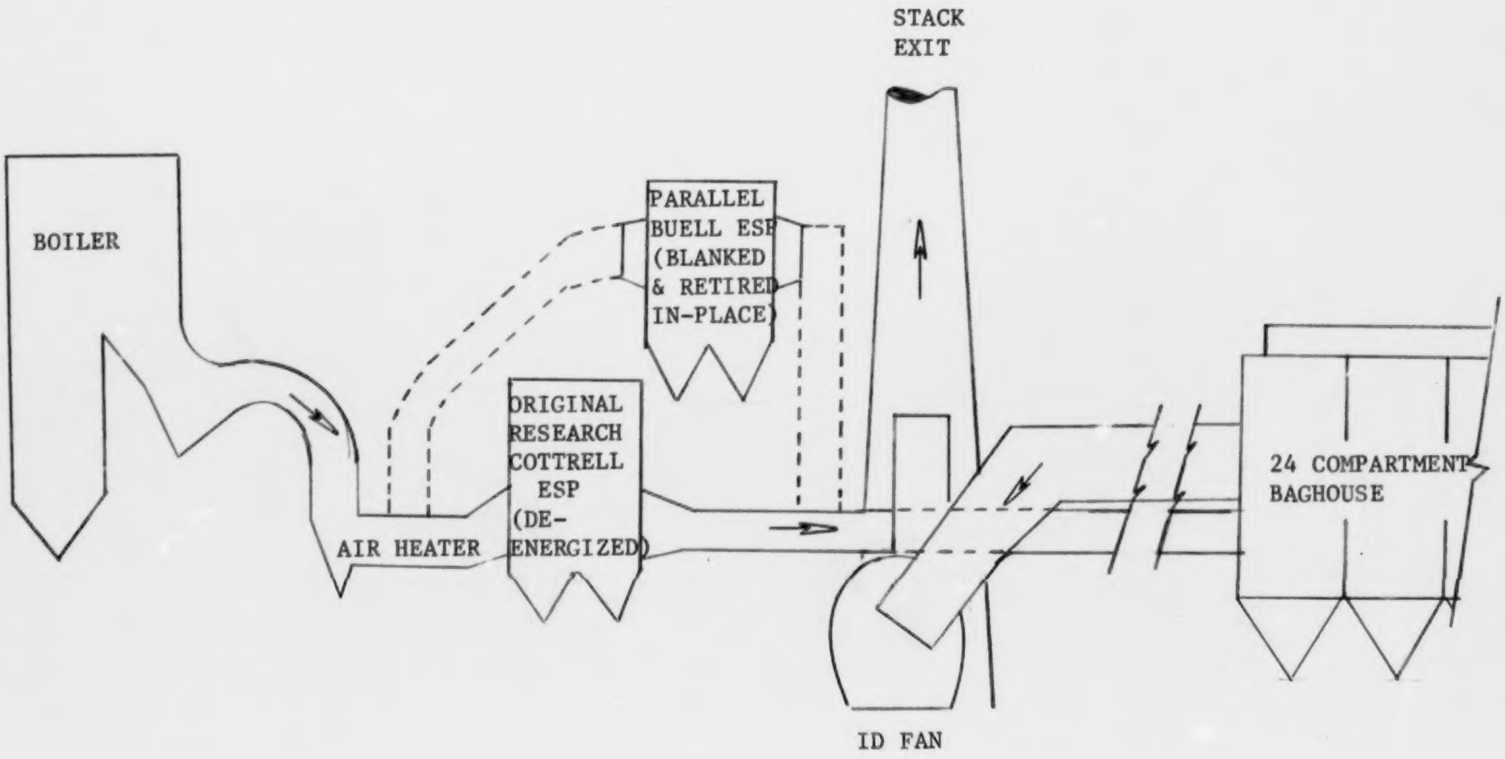

STACK
EXIT
BOILER
PARALLEL
BUELL ESP
(BLANKED
& RETIRED
IN-PLACE)
ORIGINAL
RESEARCH
COTTRELL
ESP
(DE-
ENERGIZED)
AIR HEATER
24 COMPARTMENT
BAGHOUSE
ID FAN

FIGURE 2. ORIGINAL EQUIPMENT AND FABRIC FILTER ARRANGEMENT

A. Hoppers

The twenty-four (one per compartment) pyramidal hoppers are constructed of 3/16" thick carbon steel plate in the upper two-thirds and 1/4" thick stainless steel plate in the lower third. Each hopper has one 24" square access door, three rapping anvils and a 12" diameter flanged outlet. Each hopper also has a capacitance type level detector. Hoppers are designed to hold the dust collected during at least 27.7 hours of continuous unit operation at full load. The entire hopper area is enclosed for weather protection.

B. Valve Gallery Enclosure

There is an enclosure at the top of the bag filter which houses all of the compartment ventilation, reverse air and compartment outlet damper air operators. The compartment ventilation fans are also installed in the valve gallery enclosure.

C. Insulation

1. Exterior

The entire bag filter, fans and ductwork are insulated with 5" of insulation. The prefabricated insulation panels are a combination of 2-1/2" mineral wool and 2-1/2" fiberglass. All circular duct work is insulated with 5" blankets of fiberglass. All insulation is covered with aluminum lagging.

2. Interior

Three inches of fiberglass insulation with galvanized cladding is provided within the compartments for personnel protection on all common walls between adjacent compartments and all common walls between the compartments and the inlet plenum from the tube sheet elevation up to a minimum height of seven feet. There is also internal insulation at the bag tensioning elevation between the compartment and the outlet plenum.

D. Baghouse Operation

Flue gas is drawn into the inlet manifold of each of the twenty-four (24) compartments. (Ref: Figure 3). The inlet manifold runs the entire length of the baghouse and directs the flue gas through the inlet poppet dampers and into the hopper of the bag filter compatments. The flue gas is then directed upward into each baghouse compartment under negative pressure from the I.D. fans. Particulate emissions are collected on the inside of the filter bags as the flue gas flows through the bag. The cleaned flue gas is pulled upward through the outlet poppet damper into the outlet manifold which is common to all compartments. The flue gas is then pulled from the outlet manifold into two I.D. fans and exhausted through the common stack with unit No. 2.

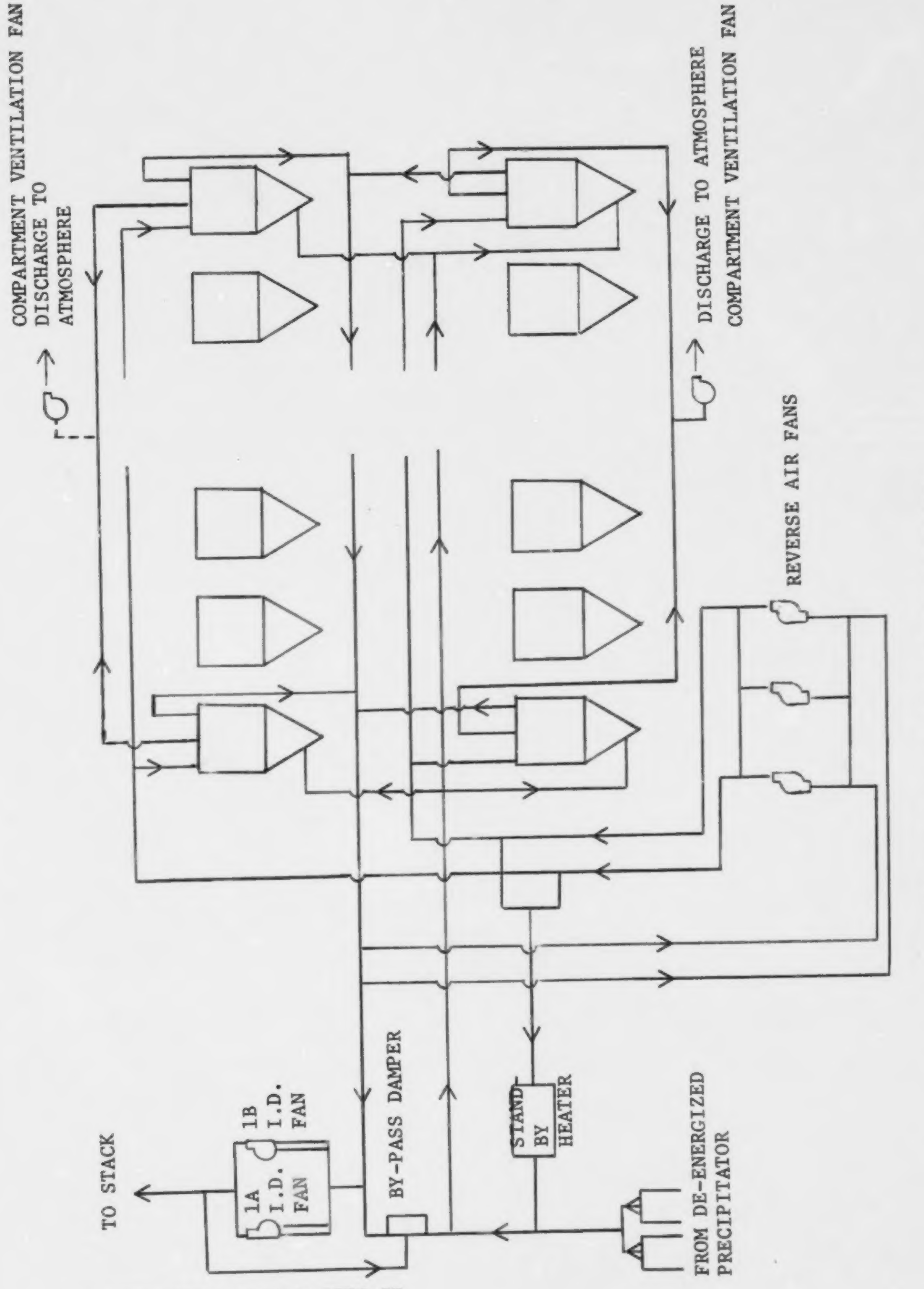

COMPARTMENT VENTILATION FAN
DISCHARGE TO ATMOSPHERE
DISCHARGE TO ATMOSPHERE
COMPARTMENT VENTILATION FAN
REVERSE AIR FANS
TO STACK
1A I.D. FAN
1B I.D. FAN
BY-PASS DAMPER
STAND-BY HEATER
FROM DE-ENERGIZED PRECIPITATOR
BY-PASS DAMPER PRESS AIR DUCT

FIGURE 3. GAS FLOW THROUGH BAGHOUSE

Reverse air cleaning is used to periodically remove dust that is collected on the interior of the filter bags. Two reverse air cleaning systems are provided, one for each 12-compartment side of the baghouse. Each compartment is connected with a poppet damper to a reverse air manifold. Clean hot air from the outlet duct is drawn through the reverse air fans and distributed to the compartment through the reverse air manifold. A spare reverse air fan has been installed with the required interconnecting ducts and dampers on each fan and are interlocked with the fan operation so that the idle fan is automatically isolated from the systems.

Timers on the control panel sequentially control the operation of all compartment outlet and reverse air dampers during the cleaning cycle.

E. Filter Bag Cleaning Operation

The baghouse can be cleaned on either a continuous timed cycle or on a differential pressure basis. One compartment per side undergoes the cleaning operation at a time with the remaining compartments "on line" collecting particulate matter.

The outlet damper of the compartment to be cleaned closes, cutting off the main dust laden gas stream. The reverse air damper opens and clean hot gas flows through the fabric in the reverse direction. The bags are prevented from collapsing by cadmium plated steel rings sewn into the bags. The collapsing action plus the reverse flow of air dislodges the dust from the inside of the bags. This dust falls into the hoppers below while the reverse air stream travels back through the open inlet damper into the inlet plenum and through the remaining operating compartments. All compartments are cleaned in turn until each has been cleaned at which point, the cycle enters the bag filter interval time. During this interval period, the baghouse cleaning cycle will not start again until the cycle is reset by the interval timer or the ΔP set point is reached. Either the timer or ΔP cleaning mode can be selected by moving a switch on the bag cleaning control panel.

The timer span between ΔP cleaning cycles depends on various factors, the most significant being inlet dust loading. The times for the cleaning cycle can be changed at the baghouse control panel. The interval timer can be adjusted to change the length of time between the bag cleaning cycles.

F. Auxiliary Equipment

1. By-Pass Damper

The by-pass damper is designed for a flue gas volume of 330,000 acfm at 300°F. The function is to allow the flue gas flow during boiler startup to bypass the baghouse compartments. Unit No. 1 boiler is normally fired with oil before introducing coal. Since the heat up process normally takes some period of time, it is possible to bypass the baghouse during this time to avoid exposure to cooler flue gas and/or fine oil ash particles. The bypass damper is activated by moving a selector switch on the baghouse control panel. The double louver bypass damper has a plenum section between the damper blades. This plenum receives clean hot air from the downstream side (positive pressure) of the I.D. fans through duct work and a repressuring damper that is open when the bypass damper is closed. This creates a positive pressure in the plenum section so there is zero percent leakage of dirty gases from the inlet duct to the outlet duct during normal baghouse operation.

2. Standby Heating System

The standby heating system is an electrical resistance type with controls to maintain the baghouse at 300°F after shutdown. The system includes 1932 KW of Chromalox, type TOH-LT tubular duct heaters with 480 volts, 3 phase, 60 Hz power supply, a temperature controller, recorder for return air temperature, alarms for high/low air temperature, and controls for utilization of any one of the three reverse air fans as the heating air circulator. During heating, all reverse air dampers and the main I.D fan dampers are closed, and all baghouse inlet and outlet dampers are open (Ref. Figure 3). Also, included is interconnecting duct work from the reverse air cleaning system to the heating chamber and to the baghouse inlet manifold, dampers to operate the reverse air fans, expansion joints, and a pressure indicator to indicate air flow through the duct.

3. Compartment Ventilation System

A compartment ventilation system was furnished to cool individual compartments to facilitate access for on-line maintenance. There are two separate 19,000 cfm systems, each to serve any of 12 compartments (Ref. Figure 3). Each sytem includes a 32" diameter poppet damper at each compartment, interconnecting ducts and manifolds to the exhauster units, two exhauster units (each including a 30 hp, 1800 rpm, TEFC motor), manually operated exhauster outlet damper for volume control, and a start-stop selector switch at the lower access door of each compartment. To start the ventilation system, a compartment must first be isolated. The selector switch will open the compartment ventilation damper of the isolated compartment and start the vent fan. Interlocks prevent the compartment from being put back into operation unless the vent system is turned off.

4. Compressed Air System

Two air compressors are installed to provide the compressed air to operate all the damper air cylinders. One operates the system and the other is a standby unit. The 75 hp compressors are Ingersoll-Rand Type 40 Model H750 BKM, each with a capacity of 268 ACFM at 150 psig.

The two air compressors are connected to a single air dryer. The desiccant air dryer is a pall Trinity Micro Coporation Model No. 501 HA 4-0000CH, heatless type with a capacity of 600 SCFM, -40°F dew point at 130-150 psig. The dryer is furnished with a mounted pre-filter, drain trap after the filter, chamber pressure gauges, purge flow indicator, moisture indicator, inlet and outlet pressure gauges, and high humidity alarm, that are all panel mounted. The dryer is connected to two (2) 1600 gallon air receiver tanks rated for storage at 150 psig, 130°F.

5. Elevator

An elevator was provided to facilitate access to all elevations of the baghouse for operation, inspection, and maintenance. The elevator is manufactured by the Otis Elevator Company and is rated for 4,000 pounds capacity at 100 fpm. Car size is 5'-8" x 9'- 1 1/2". There are five stops at the following elevations: ground, inlet damper access platform, thimble elevation, bag tensioning elevation and valve gallery enclosure elevation.

G. Controls and Instrumentation

1. Control Power

The control power is supplied from a 15 amp breaker and 7.5 KVA transformer located in the baghouse motor control center. 120V AC is then distributed within the control panel through six 15 amp fuses. The annunciator panel is supplied with 125V DC power from a separate source.

2. Panel Components

Indicating lamps are provided to show the status of all dampers, compartments, and fan motors.

H. PP&L Modifications

1. I.D. Fans

In order to accommodate the increased pressure drop because of the installation of the new bag filter and ductwork, it was necessary to upgrade the existing centrifugal I.D. fans and motors. It was also necessary to re-orient the inlet boxes of these two fans to accept the new baghouse outlet duct (Ref. Figures 1 and 2). Basically, the existing I.D. fans were rebuilt from the foundation up: new casings and inlet boxes, new larger diameter rotors, and new larger motors were installed by PP&L as part of this project.

2. Ash Handling System

The modified ash handling system on unit No. 1 consists of three independent systems which utilize hydroveyors and high pressure water to create a vacuum for ash removal. The ash removal system consists of a separate system for each baghouse row of twelve compartments and also a system for the original 1A precipitator and duct/breeching hoppers. All three systems are designed to operated simultaneously. The ash removal capacities on the baghouse systems are 48 and 49 tph and the precipitator system capacity remains unchanged at 30 tph. The baghouse ash removal system features high capacity intakes that uses diffuser stones. Low pressure air passes to increase the ash removal rate. Included on the baghouse hoppers are diffusers that are used in place of vibrators. The diffusers allow low pressure air to "fluff" the ash in the hoppers to avoid pluggage.

The fly ash from each system discharges to a slurry tank where it is sluiced to the ash basin by using two slurry pumps installed in series. One of the two pumps installed in series has a variable speed drive so that the speed of the pump can be varied to maintain a constant slurry tank level. A spare set of slurry pumps is installed to allow for on-line maintenance.

3. Opacity Monitors

Prior to the installation of the baghouse, two opacity monitors were installed on the discharge of the I.D. fans (one monitor for each fan discharge). This location was by no means ideal due to positive pressure, high vibration and poor ductwork configuration. The installation of the new baghouse provides a long straight section of outlet duct ahead of the I.D. fans providing an optimum location for the opacity monitor. An opacity monitor was installed at this location and the two opacity monitors previously located at the I.D. fans were retired.

Much of the information provided in this section was taken from prior publications by PP&L personnel.(2)(3)(4)(5)

IV. DESCRIPTION OF PP&L TEST PROGRAMS

Two separate series of tests were conducted at Pennsylvania Power and Light's Brunner Island Station. The first test program was carried out August 12-16, 1981, and the follow-up program was conducted September 2-4, 1982.

Because of Pennsylvania's state compliance requirements, emission tests performed in August of 1981 were much more inclusive. Five (5) EPA Method 5 (outlet) tests in conjuction with five (5) EPA Method 17 (inlet) tests were performed.

Two inlet, two outlet and two blank Cascade impactor tests were performed during the August, 1981, program. The impactor test series of September, 1982 included ten (10) runs: four inlet runs, four outlet runs, and two blank runs.

Baghouse and control room data, along with basic baghouse maintenace and operational data were recorded during both programs.

Test protocol followed that specified in the Federal Register and the Pennsylvania Department of Environmental Resources manual.

The results of these two programs are presented later in two (2) separate sections of this report.

A conversion table for converting British and metric units is given on page xi.

A. Test Port Locations

Sampling during both programs was conducted at seven (7) inlet and seven (7) outlet vertically arranged sample ports positioned before and after the baghouse. Seven (7) equi-distant traverse points were assigned to each of the seven inlet and outlet ports.

B. Testing Methodology

Particulate emission tests were conducted according to U.S. EPA Reference Methods 5 and 17 procedures in conjunction with Methods 1, 2, 3 and 4. An alundum thimble (Method 17) was used for testing on the inlet because the concentration of particulate matter in the gas stream to the baghouse was high. The EPA contract specified Method 5 sampling on the outlet. A Norton AN-899 5.0 μm retention alundum thimble was used in this test series to prevent vacuum problems and the extra time required to change filters and leak check. Subsequent laboratory analysis supported this decision because no more than 6.5% of the total outlet particulate catch was deposited on the Method 5 filter during any of the tests of the August, 1981 test program.

Each test included a forty-nine (49) point traverse with a five (5) minute sampling duration for each point, resulting in a total test time of four (4) hours and five (5) minutes.

The Quality Assurance Reports critiquing test protocols at PP&L may be found in Appendix 7 (test series one) and Appendix 11 (test series two).

C. Sampling Equipment and Procedures

The particulate sampling equipment used is referred to as the "EPA Particulate Sampling Train", designed and developed by the United States Environmental Protection Agency. Schematics of the equipment are shown in Figures 4 and 5.

The apparatus used consisted of a stainless steel sampling nozzle, an alundum thimble, a Method 5 filter holder containing an 87 millimeter Schleicher and Scherell #1-HV High Purity Glass Filter, a series of four (4) Greenburg-Smith impingers, a check valve, a leakless vacuum pump, a dry gas meter, and a calibrated orifice. The impingers and connecting tubes were made of Pyrex glass and were connected with glass ball and socket joints. The probe was made of type 316 stainless steel.

The first, third, and fourth impingers were modified by replacing the high velocity tip with a glass tube having an inside diameter of 1/2 inch. The first and second impingers were charged initially with 100 ml of water. The third impinger was left dry, and the fourth impinger was charged with approximately 200 grams of dry, pre-weighed silica gel. All four impingers remained packed in an ice bath during sampling.

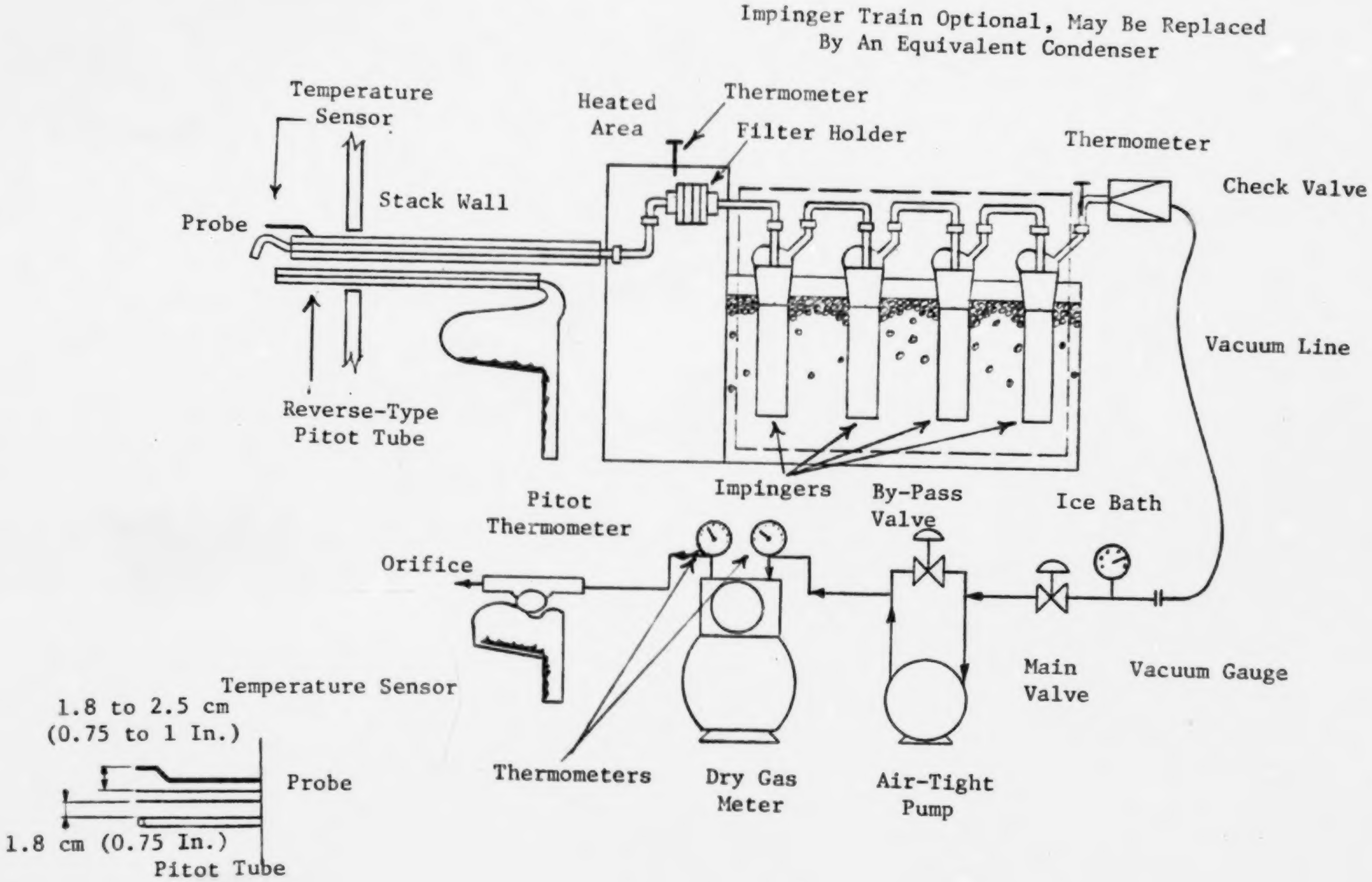
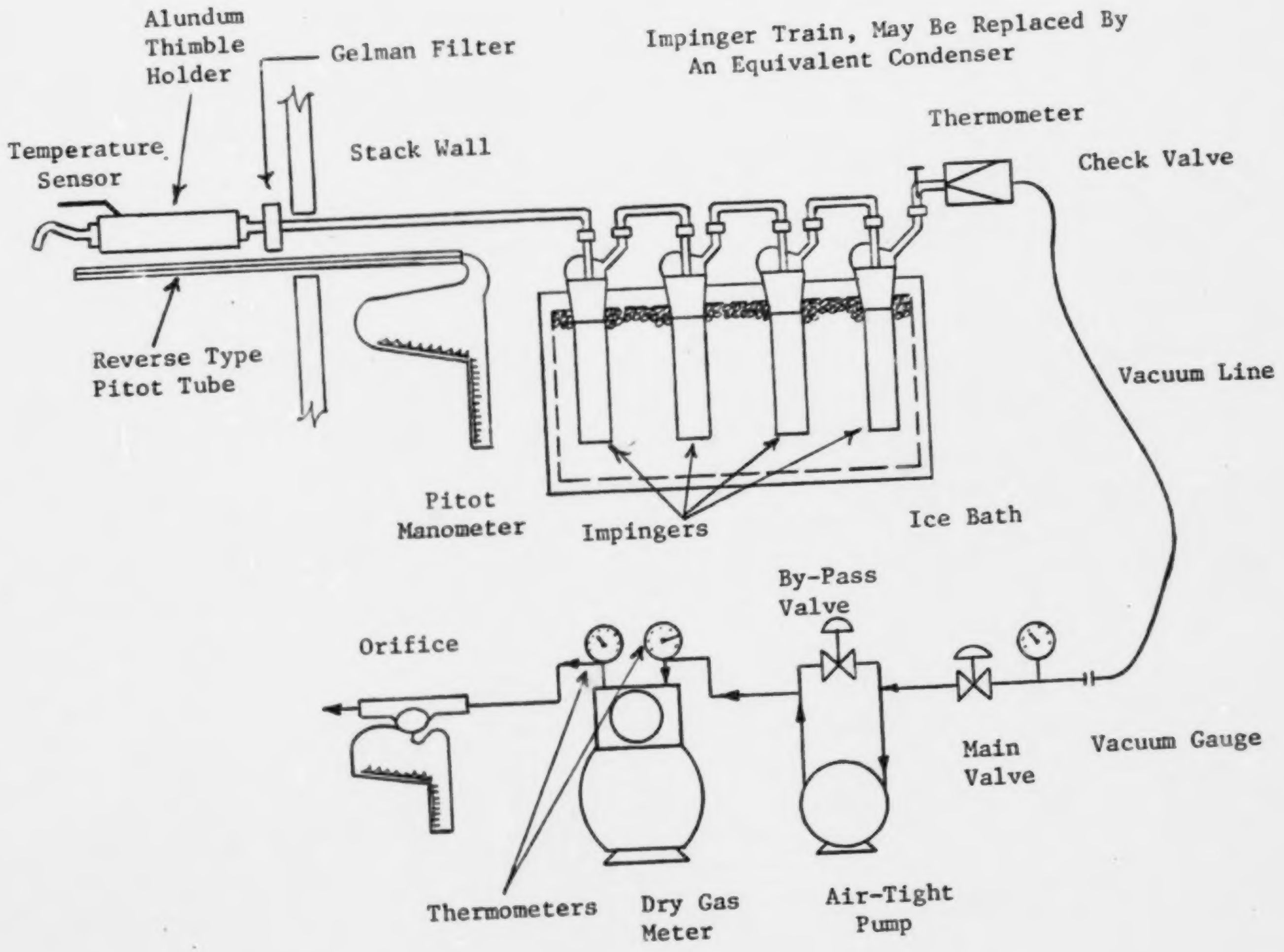

Impinger Train Optional, May Be Replaced By An Equivalent Condenser
Temperature Sensor
Heated Area
Thermometer
Filter Holder
Thermometer
Check Valve
Probe
Stack Wall
Vacuum Line
Reverse-Type Pitot Tube
Pitot Thermometer
Impingers
By-Pass Valve
Ice Bath
Orifice
Temperature Sensor
Main Valve
Vacuum Gauge
1.8 to 2.5 cm (0.75 to 1 In.)
Probe
Thermometers
Dry Gas Meter
Air-Tight Pump
1.8 cm (0.75 In.)
Pitot Tube

Figure 4. Method 5 Sampling Train



Alundum
Thimble
Holder
Gelman Filter
Impinger Train, May Be Replaced By
An Equivalent Condenser
Thermometer
Temperature
Sensor
Stack Wall
Check Valve
Reverse Type
Pitot Tube
Vacuum Line
Pitot
Manometer
Impingers
Ice Bath
By-Pass
Valve
Orifice
Main
Valve
Vacuum Gauge
Thermometers
Dry Gas
Meter
Air-Tight
Pump

Figure 5. Particulate Sampling Train

Using a Type S pitot tube, a velocity traverse was performed along all traverse axis during each test run. The velocity pressure at each sampling point was measured by means of an inclined manometer. A thermocouple was also attached to the pitot tube to measure gas stream temperature. Thermal potential was measured with an Omega portable potentiometer.

Before beginning a run, the complete sampling train including probe and nozzle was leak tested by plugging the nozzle with a rubber stopper and then applying a vacuum of 15 inches of mercury to the system. This procedure was repeated at the conclusion of each run. The maximum allowable leakage rate of 0.02 cfm was not exceeded in any of the leak tests.

During testing, isokinetic sampling conditions were achieved by maintaining the velocity of the stack gas entering the sampling nozzle eqivalent to the stack gas velocity at each sampling point. The required velocity of the stack gas entering the sampling nozzle was obtained by adjusting the pressure drop across the calibrated orifice. The pressure differential across the calibrated orifice was measured by an inclined/vertical manometer with an inclined range of 0-1.0 inches of water and a vertical range from 1.0 to 10.0 inches of water. The proper calibrated orifice pressure drop was determined by using reproductions of the nomographs contained in the publication, "Addendum to Specifications or Incinerator Testing at Federal Facilities".

At the completion of each test, the sampling nozzle, inside the probe, inside of the thimble holder and the front half of the glass fiber filter holder were washed with deionized water and then acetone. The washings were collected in separate storage containers. The alundum thimble and the glass fiber filter were removed from their respective filter holders and stored in separate storage containers. The contents of the first three impingers were measured and then stored. The silica gel from the fourth impinger was transferred to a separate storage container. All storage containers were returned to the laboratory for analysis.

V. SUMMARY OF RESULTS FOR FIRST BRUNNER ISLAND TEST SERIES

Results for particulate emision tests performed August 12 - 16, 1981 at PP&L Brunner Island Unit 1, Steam Electric Station are summarized in Table 1. The average particulate emission rate for these five (5) tests shown in Table 1 was 0.037 lbs/10^6 Btu as compared to Pennsylvania Department of Environmental Resources allowable emission rate of 0.10 lbs/10^6 Btu.

A total of six (6) Cascade impactor tests were performed; two (2) inlet, two (2) outlet, and two (2) blank runs. Average mass mean diameters were 13.4 um at the inlet and 7.0 um at the outlet. Impactor tests indicated that the baghouse collected more than 99.9% of the particulate matter in the flue gas.

Tests to determine carbon dioxide, oxygen and carbon monoxide were conducted using an Orsat analysis according to EPA Method 3. Inlet and outlet Orsat measurements for runs one (1) through five (5) are listed in Table 1 - Test Data. Particulate test calculations, such as flue gas volume, flue gas velocity, and percent isokinetics were performed by computer. These data may be found in Appendix 6.

TABLE 1

TEST DATA SUMMARY, TEST SERIES 1, PP&L BRUNNER ISLAND

UNIT 1 - 8/12/81 - 8/16/81

RUN & DATE	Particulate Emissions Outlet lbs/10^6 Btu	Particulate Emissions Outlet lbs/hr	Particulate Emissions Outlet gr/ACF	Particulate Loading Inlet lbs/hr	Particulate Loading Inlet gr/ACF	Flow Inlet ACFM DSCFM	Flow Outlet ACFM DSCFM	Inlet Temp. °F	Outlet Temp. °F	Orsat % CO_2 Inlet Outlet	Orsat % O_2 Inlet Outlet	Orsat % CO Inlet Outlet	Stack Gas Moisture In: Out:	MW Production	Baghouse Differential Pressure@ Baghouse	Baghouse Collection Efficiency
Run 1 8/12/81	0.027	85.0	0.0085	52000	6.16	980000 600000	1170000 730000	286	294	13.1 12.2	5.4 6.0	0.0 0.1	11.0 5.7	337	8.0	99.8
Run 2 8/13/81	0.018	53.0	0.0056	29000	2.96	1140000 710000	1110000 680000	290	289	12.7 12.9	5.4 5.3	0.0 0.2	8.1 7.8	345	8.1	99.8
Run 3 8/14/81	0.078	273	0.025	37000	3.88	1110000 690000	1250000 780000	290	280	12.1 12.9	5.7 5.3	0.0 0.1	9.1 7.6	341	7.9	99.2
Run 4 8/15/81	0.037	128	0.012	42000	4.32	1140000 710000	1260000 780000	293	282	13.0 13.1	5.3 5.3	0.0 0.1	8.1 7.6	340	8.3	99.7
Run 5 8/16/81	0.026	91	0.008	45000	4.66	1120000 690000	1330000 790000	300	289	13.1 13.1	5.2 5.2	0.0 0.0	7.6 6.8	340	8.5	99.8

VI. DISCUSSION OF RESULTS - FIRST TEST SERIES

Boiler and baghouse operating conditions remained within the expected range with the exception of high pressure drop measurements across the baghouse. Measurements for parameters, such as temperature, boiler load, opacity and baghouse collection efficiency fell within the same range as usually measured for Unit 1.

Siginificant quantities of dust were observed on the clean air side of compartment 6 by ETS personnel. This compartment was off stream during the test series and would not have affected the outcome unless it was representative of other compartments.

Data related to flue gas measurements, such as flue gas volume, Orsat analyses, percent moisture, and molecular weight, may be found in Appendix 6. Flue gas volumes of the five (5) full load tests fell within the expected range for each run with two exceptions. Measured inlet volumes for Run 1 in ACFM and DSCFM were both below the expected and actual volumes of Runs 2 through 5. Also, the volumetric flow rate decreased from inlet to outlet for Run 2 by approximately 6%. The pitot tube has an accepted accuracy of ± 20%. Therefore, the discrepancy of the inlet and outlet flow rates may be attributed to the accuracy of the pitot tube. In addition, the probe was bent during portions of Runs 1 and 2. This also could have contributed to the flow rate discrepancy.

It was suspected that the addition of the alundum thimble unit to the outlet probe assembly could have affected the pitot tube coefficient and, consequently, the flow measurements, since this probe assembly was built to accommodate the Method 5 components only. However, actual field calibration using the standard and S-type pitot tube indicated that the repositioning of the S-type pitot tube along side the alundum thimble such as was done at Brunner Island Unit 1 outlet did not change the pitot tube coefficient.

The moisture measurement of inlet Run 1 was abnormally high. Any problems related to silica gel were discounted by reweighing the silica gel used in Runs 3, 4 and 5 in the field and obtaining the same weight as that measured in the laboratory prior to testing. Also, moisture collected by the silica gel alone was no greater than 1.6% for any of the five tests.

Heat input measured in Btu/hr was determined from direct enthalpy calculations by using boiler data that were collected in the control room. For comparison purposes, emission rates were also calculated according to the F-factor method and are listed in Table 2. A third F-factor calculation assuming a flow of 9,820 DSCF/10^6 Btu according to the Code of Federal Regulations 40CFR60.46, are listed in the computer printouts in Appendix 6. Individual F-factors derived for each of the five (5) particulate tests and the associated emission rates in lbs/10^6 Btu are given in Table 3.

TABLE 2

HEAT INPUT BTU/HR - F-FACTOR CALCULATION

TEST SERIES 1
PP&L
BRUNNER ISLAND

UNIT 1

AUGUST 10-19, 1981

RUN NO.	ENTHALPY CALCULATIONS	F-FACTOR CALCULATION
1	3.15×10^9 Btu/hr	3.14×10^9 Btu/hr
2	3.23×10^9 Btu/hr	3.55×10^9 Btu/hr
3	3.16×10^9 Btu/hr	3.58×10^9 Btu/hr
4	3.22×10^9 Btu/hr	3.57×10^9 Btu/hr
5	3.17×10^9 Btu/hr	3.75×10^9 Btu/hr

TABLE 3

TEST SERIES 1

BRUNNER ISLAND - UNIT 1

AUGUST 10 - 16, 1981

F-FACTOR CALCULATIONS

$$\text{F-factor} = 10^6 \frac{\left[3.64\ (H) + 1.53\ (C) + 0.57\ (S) + 0.14\ (N) - 0.46\ (O_2)\right]}{GCV}$$

where H = % hydrogen by weight

C = % carbon by weight

S = % sulfur by weight

N = % nitrogen by weight

O_2 = % oxygen by weight

GCV = gross calorific value of coal in Btu/lb

Percentages taken from ultimate analysis of coal.

$$\text{Emission rate} = (\text{LBS/DSCF})\ (\text{F-factor})\ \left(\frac{20.9}{20.9 - \%O_2}\right)$$

Run No.	% H	%C	%S	%N	$\%O_2$	GCV	F-Factor	LBS/HR
1	5.37	70.43	1.94	1.43	5.07	12,956	9,747	0.027
2	4.89	67.76	1.96	1.29	5.97	12,408	9,673	0.017
3	4.75	71.24	2.20	1.35	6.43	12,942	9,641	0.077
4	4.38	71.21	2.36	1.36	5.15	12,850	9,655	0.036
5	4.59	70.01	1.76	1.40	6.58	12,827	9,511	0.025

An ultimate and proximate fuel analysis of coal samples taken during each of the five (5) particulate tests were performed by Norfolk Testing Laboratories in Norfolk, Virginia. Approximately one-half pound coal samples were taken from each of the coal mills of Unit 1 during each hour. At the conclusion of each run, the accumulated sample was reduced to approximately a two-pound integrated sample which was then analyzed. Coal parameter concentrations remained within an expected and consistent range. Tabulated lists of the coal analysis may be found in Appendix 4.

As stated earlier in the results summary section, outlet particulate emisions for the particulate tests performed at Brunner Island Unit 1 averaged 0.037 lbs/10^6 Btu. Emission rates are also expressed in lbs/hr and averaged 126.0 lbs/hr for the five (5) outlet tests. Inlet emissions for Unit 1 averaged 13.08 lbs/10^6 Btu or 41,000 lbs/hr. Inlet Run 1 was higher than the next closest inlet loading rate by approximately 7,000 lbs/hr. The most probable cause of this aberration is that some dust was scrapped or shaken loose from inside a flange or the duct work during the first emission test by the bent probe. This belief is also supported by the fact that the inlet grain loading (3.43 gr/ACF) measured during the first Cascade impactor test of the same day is nearly one-half of that measured during the first particulate emission test (6.16 gr/ACF).

Outlet emissions for Run 3 of 273.1 lbs/hr were calculated to be more than twice the rate of the next highest outlet emission. It should be noted that Run 3 was the first run during which an alundum thimble was used. The higher loading rate for Run 3 may have been caused by dust re-entrainment from the dust on the clean side of the baghouse or associated duct work. Also, some variation in outlet emissions is expected. It is possible that the filter may have been contaminated. It should also be noted that of the total catch for Run 3 (715 mg), 636 mg was caught in the probe.

During inlet tests 2 and 3, alundum thimbles were replaced before the last port (G) was tested. This enabled these two emision tests to be treated as two separate emission tests each run; i.e. test 2A (testing of ports A-F) and 2B (testing of port G). The end result is the generation of three (3) particulate emission rates for inlet tests 2 and 3. The emission test for ports A-G of Run 2 resulted in a grain loading of 2.96 gr/ACF while an individual analysis of the thimble catch for port G yielded a grain loading of 5.67 gr/ACF, nearly twice that expected for uniform loading for ports A-G. Comparative analysis for inlet Run 3 yielded similar results. Total grain loading for ports A-G resulted in a 3.88 gr/ACF loading rate as compared to a loading rate of 6.2 gr/ACF for port G, that is nearest the bottom of the duct. This may have occurred because of the larger particles gravitating to the bottom of the duct. These results are listed in Table 4.

TABLE 4

GRAIN LOADING COMPARISON FOR PORTS

TEST SERIES 1

PP&L

BRUNNER ISLAND - UNIT 1

AUGUST 10 - 19, 1981

RUNS 2 and 3 INLET

	LBS/HR PORTS A - G	LBS/HR PORT G	GR/ACF PORTS A - G	GR/ACF PORT G
RUN 2	28,514	8,026	2.96	5.6
RUN 3	35,383	8,616	3.88	6.2

Results of previous emission tests conducted at Brunner Island Unit 1 are given in Table 5.

A Bahco particle size analysis was performed on a sample of particulate matter collected in the inlet thimbles during the August 12-16, 1981 testing program. Results of the Bahco particle size analysis are given in Appendix 3. These results are presented as cumulative probability graphs and should be read as cumulative percent smaller than stated size on a weight basis. Table 6 compares the Bahco analysis with the MRI impactor results.

The Bahco Micro-Particle Classifier is an air centrifuge-elutriator comprised of a brush feed system and a rotor assembly driven by a 1 HP, 200 volt, 3 phase motor. This motor creates precisely controlled air velocities, which depending on the size, form and weight of the subject particles, directs these particles in a specific direction in an air current. The air flow can be adjusted which allows the grain size limit of division to be varied, resulting in the material being divided into any number of fractions with limited grain size ranges.

Bahco analysis performed on the inlet thimble catch for Runs 1, 2 and 4 were relatively consistent with an average mean size of 14.1 µm. Runs 3 and 5 resulted in what appears to be considerably higher average particle sizes of 28.5 µm and 24.0 µm, respectively.

PARTICULATE EMISSION TESTS CONDUCTED BY GILBERT/COMMONWEALTH
DECEMBER, 1980

TABLE 5

TEST DATA SUMMARY - PP&L BRUNNER ISLAND - UNIT 1

Run No. & Date	Particulate Emissions Outlet Lbs/10^6 Btu	Particulate Emissions Outlet - Lbs/hr	Particulate Emissions Inlet - Lbs/Hr	MW Production	Flow Inlet ACFM DSCFM	Flow Outlet ACFM DSCFM	Inlet Temp. °F	Outlet Temp. °F	Grains/ACFM Inlet	Grains/ACFM Outlet	Baghouse Collection Efficiency	Stack Gas Moisture In: Out:
Run 1 12/9/80	0.019	66.0	29000	343	1050000 659000	1030000 660000	303	285	3.15	0.029	99.8	6.7 6.6
Run 2 12/10/80	0.020	62.0	27000	341	1070000 680000	1190000 760000	300	291	2.93	0.198	99.8	6.5 5.8
Run 3 12/11/80	0.016	49.3	26000	350	1090000 690000	1140000 730000	305	291	2.71	0.018	99.8	6.4 5.8
Run 4 12/12/80	0.018	57.6	24000	345	1080000 670000	1150000 730000	307	295	2.49	0.019	99.8	6.6 6.0
Average	0.018	58.7	26000	345	1070000 670000	1130000 720000	304	291	2.82	0.066	99.8	6.6 6.1

TABLE 6

PARTICLE SIZE ANALYSIS COMPARISON

TEST SERIES 1

PP&L

BRUNNER ISLAND

AUGUST 10 - 19, 1981

TECHNIQUE	gr/ACF	gr/SCF	AVG. MEAN DIAMETER (μm)
Bahco Analysis Run 1 Inlet			16.5
MRI Impactor Run 1 Inlet	3.43	2.15	12.7
MRI Impactor Run 1 Outlet	0.0032	0.002	6.6
Bahco Analysis Run 2 Inlet			13.5
MRI Impactor Run 2 Inlet	4.19	2.68	14.0
MRI Impactor Run 2 Outlet	0.0029	0.0018	7.4
Bahco Analysis Run 3 Inlet			28.5
Bahco Analysis Run 4 Inlet			12.3
Bahco Analysis Run 5 Inlet			24.0

Temperature measurements taken at the inlet and outlet during the particulate tests may be found in the computer printouts in Appendix 6. A problem was encountered in obtaining accurate outlet test port temperatures during the tests. As a result of empirical tests and calibrations performed in ETS' laboratories, a calibration curve has been created that enables proper interpretation of these data (refer Figure 6). Figure 6 depicts actual outlet temperature derived from the curve for Runs 1 through 5. These numbers differ from those taken from the baghouse control room because the temperature measured during the particulate tests by the ETS crew were taken at forty-nine (49) points throughout the duct work while the baghouse temperature, as read in the control room, is a one point measurement probably taken by a thermocouple wire located at the outlet duct mid-point.

Cascade impactor sampling was performed by D. S. Ensor, et al, August 11 through 14, 1981. Impactor results may be found in Appendix 2 as a separate report. A total of two (2) inlet, two (2) outlet blank impactor tests were performed. Mean particle size was 13.4 µm at the inlet and 7.0 µm at the outlet. These results are compared with Method 5 grain loadings in Table 7. Inlet and outlet size distribution curves for the particle sizing tests may be found in Figures 7 and 8.

FIGURE 6

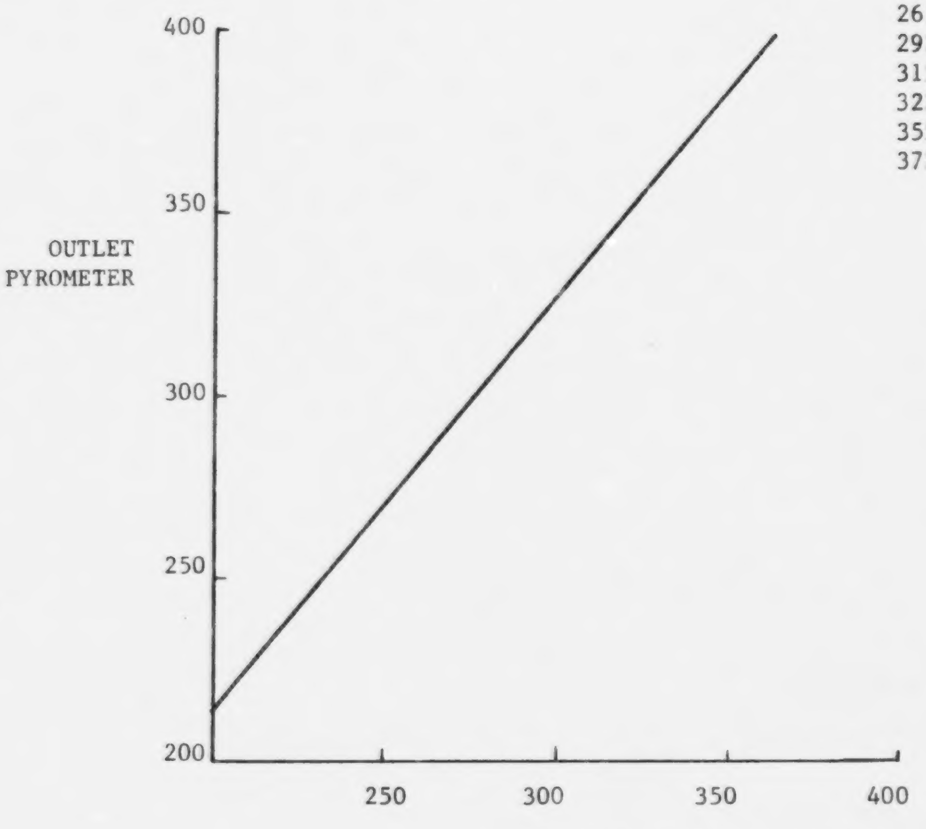
OUTLET TEMPERATURE CALIBRATION CURVE

PP&L

BRUNNER ISLAND

August 10 - 19, 1981

OUTLET TEMP. °F	CORRECTED TEMP. °F
226	213
247	229
261	237
292	268
315	287
322	293
355	321
372	340



ETS CALIBRATED PYROMETER #2
CORRECTED TEMPERATURES

TABLE 7

TEST SERIES 1

GRAIN LOADING FOR RUNS 1 & 2

PP&L

BRUNNER ISLAND

AUGUST 12 - 16, 1981

RUN NO. & DATE	IMPACTOR LOADING RATES	PARTICULATE LOADING METHOD 5
Inlet Run 1 8/13/81	3.43 gr/ACF	6.16 gr/ACF
Inlet Run 2 8/13/81	4.19 gr/ACF	2.96 gr/ACF
Outlet Run 1 8/12/81	0.0032 gr/ACF	0.0085 gr/ACF
Outlet Run 2 8/13/81	0.0029 gr/ACF	0.0056 gr/ACF

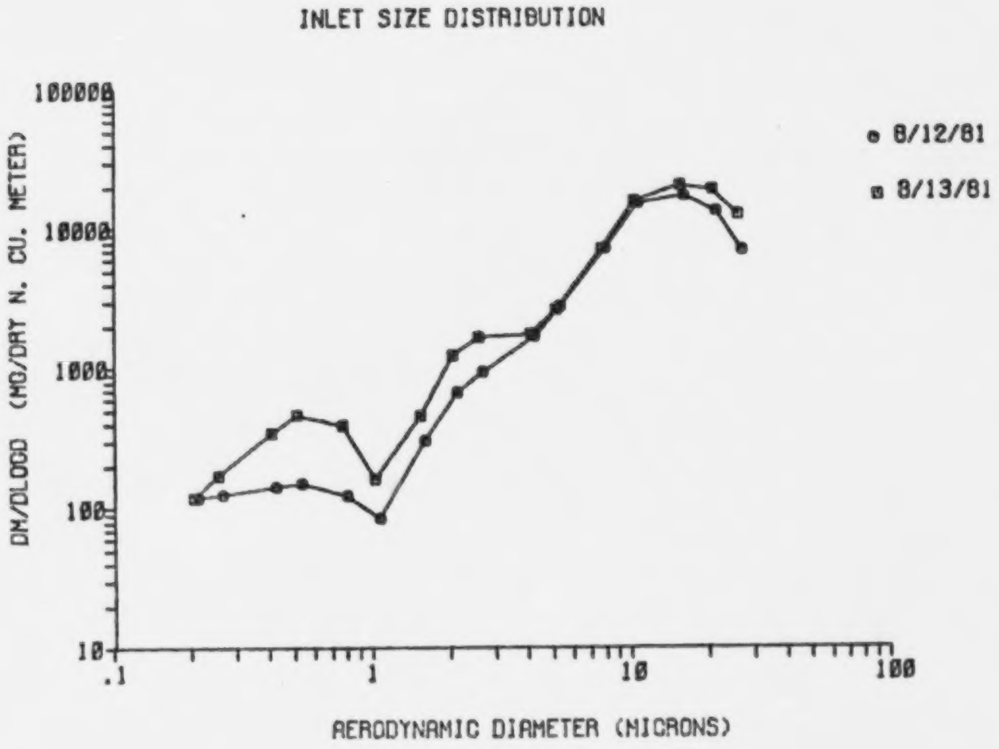


Figure 7. Inlet particle size distribution measured with MRI impactor.

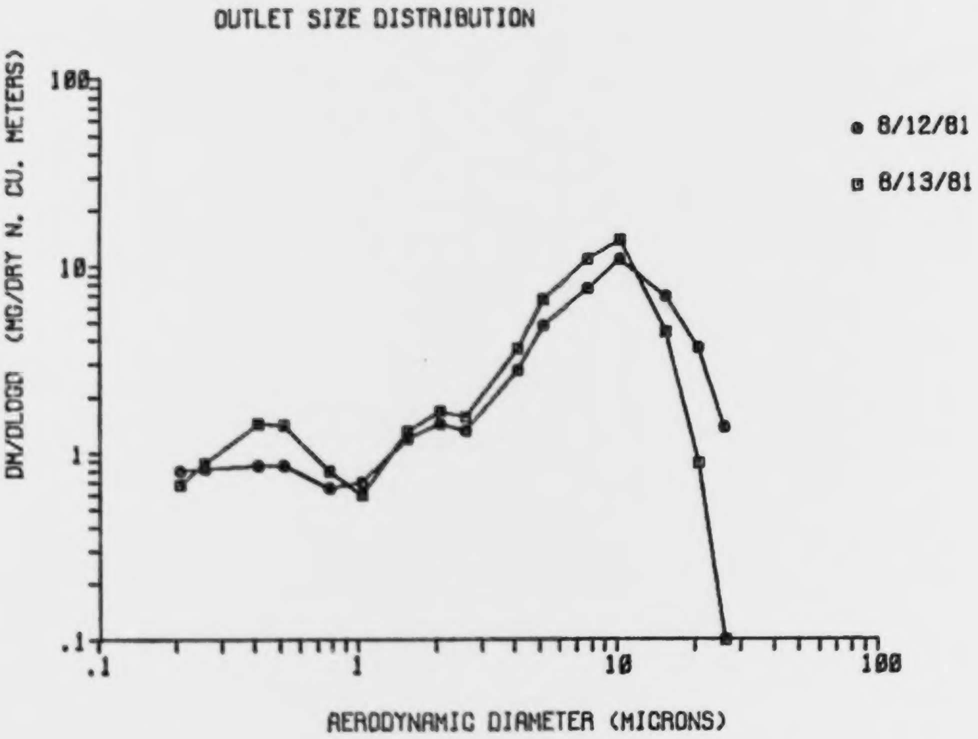


Figure 8. Outlet particle size distribution measured with MRI impactor.

Figure 9 shows the particle size of the particles that penetrated through the bags. This curve indicates that, overall, the baghouse collected larger particles more efficiently than smaller size particles.

Bag analysis were performed at ETS' laboratory in Roanoke, Va. These data may be found in Appendix 5. The entire battery of bag tests were performed including permeability, tensile strength, MIT flex and Mullen Burst. A total of six (6) bags (4 used and 2 new) were tested in September, 1981. Two bags were also tested in June of 1982. These results along with the results of the bag testing done in September, 1981, may be found in the analysis of operation and maintenance data section of this report.

Laboratory analytical procedures incorporated are those mandated by the Federal Register Part II, Environmental Protection Agency, Revision Reference Methods 1-8 and the State of Pennsylvania Department of Environmental Resources, "Source Testing Manual".

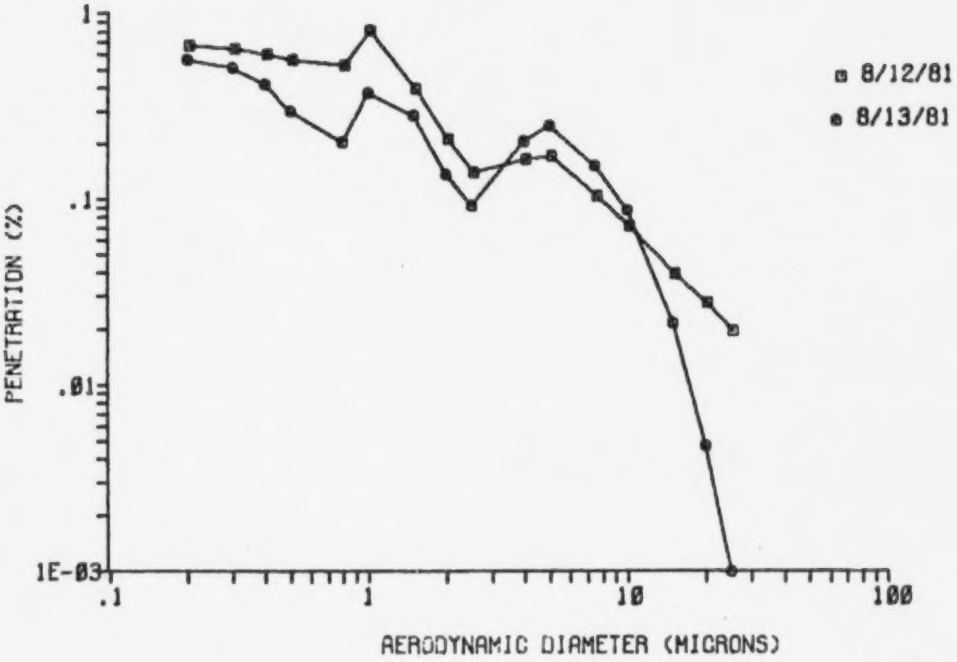


Figure 9. Particle size dependent particulate penetration through the baghouse.

VII. DESCRIPTION OF SECOND BRUNNER ISLAND TEST SERIES

A second series of particulate tests and impactor tests were conducted at the Brunner Island Unit 1 Station September 2-4, 1982. The same objectives were incorporated into the program as the test program of August 1981.

Test protocol, test port locations and sampling equipment were also the same as that used in the first test program.

VIII. SUMMARY OF RESULTS - SECOND TEST SERIES

Results of the three (3) inlet-outlet particulate emission tests performed September 2-4, 1982 are summarized in Table 8. The average particulate emission rate for the outlet tests was 0.096 lb/10^6 Btu and 7.28 lb/10^6 Btu for the inlet tests. The outlet emission rate was considerably higher than the 0.037 lb/10^6 Btu rate of August, 1981; yet still below the Pennsylvnia Department of Environmental Resources allowable emission rate of 0.10 lbs/10^6 Btu.

The impactor test series included ten runs: four (4) inlet runs, four (4) outlet runs and two (2) blank runs. A summary of the impactor tests may be found in Table 9. Computer manipulation of these data showed two peaks each for both the inlet and outlet runs.

TABLE 8

TEST DATA SUMMARY, TEST SERIES 2, PP&L BRUNNER ISLAND

UNIT 1 - 9/2/82 - 9/4/82

Run & Date	Particulate Emissions Outlet lbs/10^6 Btu	Particulate Emissions Outlet lbs/hr	Particulate Emissions Outlet gr/ACF	Particulate Loading Inlet gr/ACF	Particulate Loading Inlet lbs/hr	Particulate Loading Inlet lbs/10^6 Btu	Flow Inlet ACFM DSCFM	Flow Outlet ACFM DSCFM	Inlet Temp. °F	Outlet Temp. °F	Orsat % CO_2 Inlet Outlet	Orsat % O_2 Inlet Outlet	Orsat % CO Inlet Outlet	Stack Gas Moisture In: Out:	MW Production	Baghouse Differential Pressure@ Baghouse	Baghouse Collection Efficiency
Run 1 9/2/82	0.071	251	0.021	1.77	17000	6.18	1140000 670000	1370000 820000	315	318	13.0 13.0	6.0 6.0	0.0 0.0	11.0 5.1	335	8.4	98.6
Run 2 9/3/82	0.104	395	0.032	2.35	25000	7.84	1230000 720000	1440000 890000	308	306	12.8 12.6	6.0 6.2	0.0 0.0	11.1 4.2	335	8.0	98.4
Run 3 9/3/82	0.114	397	0.035	2.43	24000	7.82	1160000 690000	1340000 820000	314	311	12.5 12.5	6.3 6.4	0.0 0.0	9.2 4.8	335	8.2	98.3

TABLE 9

SUMMARY OF IMPACTOR TESTS AT BRUNNER ISLAND STATION

SAMPLING DATE	TEST RUN NO.	RUN TYPE	PORT	SAMPLING TIME	SAMPLING RATE (ACFM)	MASS LOADING (GR/DSCF)
9/1/82	1	blank	B	100 min.	0.496	-
9/3/82	2	blank	C	46 min.	0.288	-
9/2/82	3	inlet	C	1 min.	0.372	2.35
9/2/82	4	inlet	C	1 min.	0.428	2.37
9/2/82	5	outlet	E	4 hrs.	0.556	0.034
9/2/82	6	outlet	D	4 hrs.	0.587	0.029
9/3/82	7	inlet	C	2 min.	0.414	2.94
9/3/82	8	inlet	C	2 min.	0.408	3.24
9/3/82	9	outlet	E	100 min.	0.636	0.056
9/3/82	10	outlet	D & E*	132 min.	0.709	0.056

* Sampling was started in Port D and moved to Port E after 1 hr. and 10 min.

The curves for the four (4) inlet runs show peaks at >20 µm and 0.4 µm. The curves for the four (4) outlet runs show peaks at 9.0 µm and 0.4 to 0.5 µm. Mass mean diameters were 19.9 µm at the inlet and 9.0 µm at the outlet. A more detailed description of the impactor tests may be found in Appendix 8.

IX. DISCUSSION OF RESULTS - SECOND TEST SERIES

Boiler and baghouse operating conditions remained within the expected ranges except for the continuous problems with high pressure drop measurements across the baghouse. Control room data monitored during the test period compared closely with the data of the previous test series and with normal daily operations.

Data, such as flue gas volumes, Orsat measurements, percent moisture and molecular weights may be found in Appendix 10. Flue gas volumes for the three (3) inlet and outlet tests were found to be within the expected range. Average inlet volumes from the two test series were quite close. Average outlet volume measured during the second test series of September 1982 was somewhat higher than the average outlet volume of the August, 1981 test series. Average outlet volumes differed by approximately 10,000 acfm which is an indication that more inleakage occurred during the second test series.

Just as was observed during the August 1981 tests, inlet moisture measurements, especially inlet runs 1 and 2, were somewhat high. Outlet moisture measurements were found to be lower than measurements of the first test series.

Coal samples were collected each day emission tests were performed for the subsequent proximate fuel analysis. Both moisture and ash contents of the coal from the 1982 tests were higher than the coal burned during the previous tests. Other coal parameters remained about the same. Coal analysis results may be found in Appendix 9.

Outlet particulate emissions for the particulate tests performed during September, 1982 averaged 0.096 lbs/10^6 Btu, or 348 lbs/hr. Inlet emissions averaged 7.28 lbs/10^6 Btu or 22,000 lbs/hr. Outlet emissions were higher for the second test program and inlet emissions were nearly one-half that of the first test program. Each of the three outlet emission rates fell within a smaller range than the outlet numbers of the first test series. This also held true for the inlet results (Ref. Table 8).

Impactor sampling was also conducted at the inlet and outlet of the baghouse using a MRI inertial Cascade impactor. Sample protocol and details of sampling results may be found in Appendix 8. Impactor sampling was performed by RTI personnel. Particle size distributions are presented as a function of inertial aerodynamic diameter. Calculations were made for both total particulate mass and as a function of particle size. The results are expressed as percent penetration.

Figures 10 and 11 depict the results of the four (4) impactor inlet runs and the four (4) impactor outlet runs.

The trend of increasing penetration with particle size in the 1.0 to 10.0 μm range is depicted in Figure 12. This phenomenon, which has been observed in other baghouses, may be due to seepage through the bags. A more detailed description of this curve may be found in Appendix 8.

Temperature measurements for the inlet and outlet tests were fairly consistent and considered more accurate than those obtained during the first tests. Again, inlet temperatures measured at the duct-work and stack, and automatically recorded in the baghouse control room, were higher than temperatures measured by the stack test crew. Yet, corresponding outlet temperatures, as measured by the stack crew, were very close to those measured in the control room. One questionable pair of data points show an increase in temperature from inlet to outlet as measured by the stack crew during Run 1.

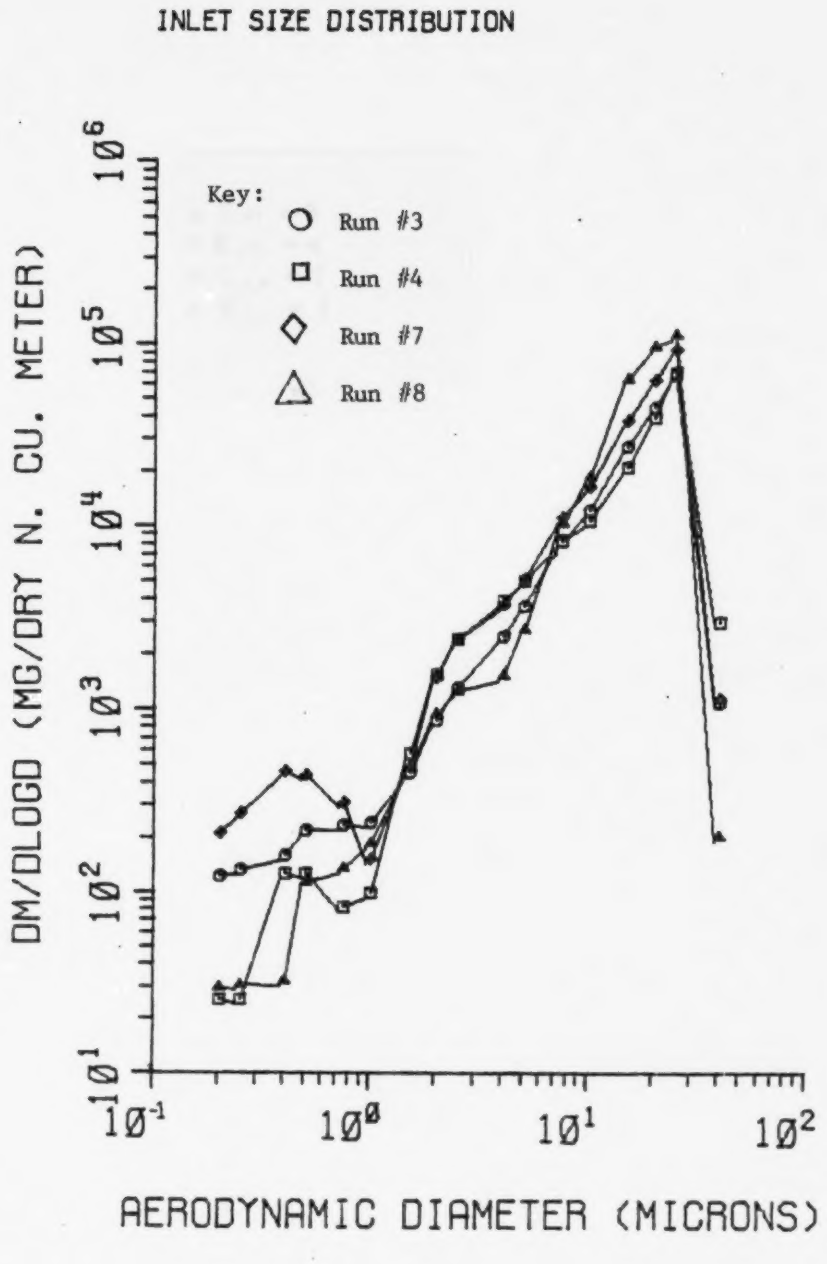


Figure 10. Inlet Dize Distribution

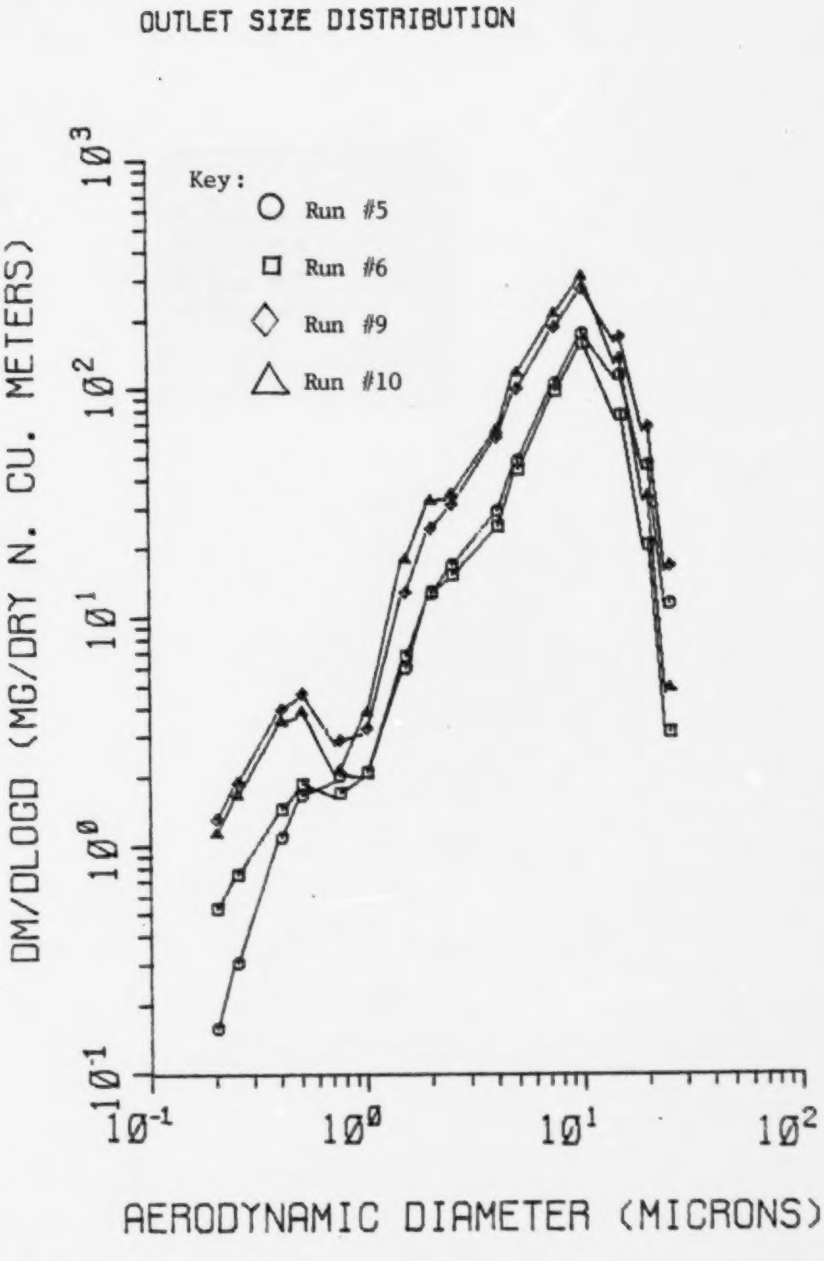
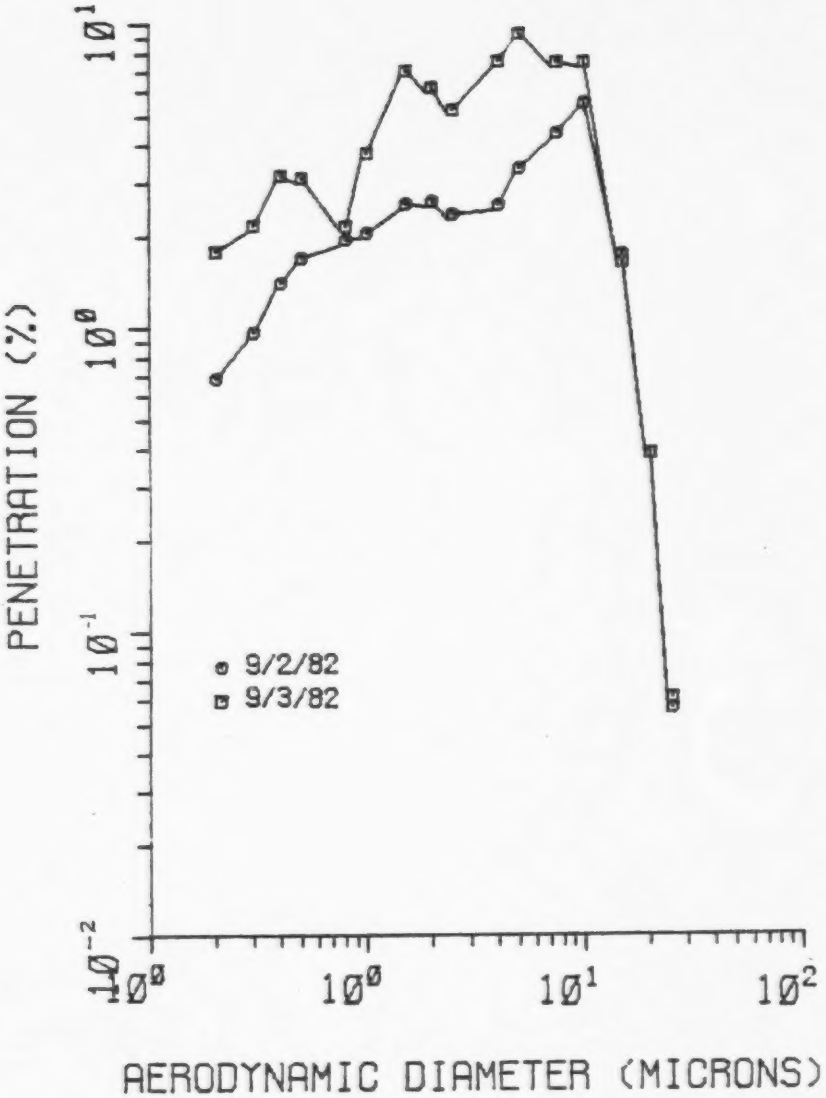


Figure 11. Outlet Size Distribution



PENETRATION VS. PARTICLE DIAMETER

Figure 12.

No significant increase in baghouse differential pressure occurred during the follow-up test series, as compared to the initial set of test i.e., (8.2 Δ P vs. 8.15 Δ P).

Opacity fluctuated throughout the tests, but remained in the ten (10) percent range or less for most of the test period.

X. O&M ANALYSIS AND DISCUSSION

Beginning with baghouse start-up, October 19, 1980 and covering a period through September 31, 1982, key data were collected daily by PP&L operators and continuously recorded onto strip chart recorders. These O&M records were examined and summarized by ETS personnel.

Initially, baghouse maintenance at Brunner Island Unit 1 entailed close monitoring of stack opacity and inspecting the individual compartments every two weeks. No specific written maintenance schedule was established. As more and more O&M problems occurred, maintenance checks were initiated by increases in opacity and bag failures.

The major maintenance problem at Brunner Island, Unit 1 was very poor bag life. Only 6 bag failures occurred in the approximate two and one-half month operation of 1980. Bag failures rose to 210 in 1981, most of which occurred during the last quarter. As of

Sept. 30, 1982, 624 bags had failed in the baghouse since start-up. By the end of 1982, almost 17%, or 1,064 bags, had failed. As a result, over 6500 manhours were required for baghouse maintenance in 1982.

PP&L has related many bag failures to improper bag tensioning. It is also suspected by PP&L that insufficient cleaning contributed to the bag failure problem. A more detailed discussion of bag failures may be found on page 72.

By far, the most significant operating problem encountered was that of rising pressure drop across the baghouse. At start-up, and soon after, monthly average high pressure drop at full load was about 4" VWC. Monthly average high values were obtained by averaging for each month the highest value for each day of that month (see Table 10 and also Figure 13). Pressure drop began to increase around April of 1981 to an average of 5.2" VWC. At this time, the cleaning cycle was changed from a pressure drop triggered (4" VWC) cleaning cycle to a continuous cleaning cycle where each compartment was cleaned every 30 minutes. In spite of this change, monthly average high pressure drop rose to the 7-8" VWC range by the end of 1981. By mid-1982, the pressure drop was reaching 9" VWC across the baghouse at full load conditions with all compartments in service. PP&L believes that this abnormally high pressure drop contributed to the bag failure rate. They also believe that the cause of the pressure drop problem was a very heavy layer of dust on the bags and the formation of nodules in the filter cake.

TABLE 10. OPERATING PARAMETERS - MONTHLY AVERAGE OF TYPICAL DAILY VALUES

	P "H_2O			SO_2 PPM			TEMPERATURE °F				STEAM FLOW 1000$\frac{lb}{hr}$			AIR FLOW 1000$\frac{lb}{hr}$			OPACITY %		
	Hi	Lo	Avg	Hi	Lo	Avg.	In	Out	Avg.	Diff.	Hi	Lo	Avg.	Hi	Lo	Avg.	Hi	Lo	Avg.
10/80	7.3	5.6	6.5	1400	1140	1270					2170	1930	2070	1920	1510	1720	4.5	3.4	3.9
11/80	4.3	4.0	4.1	1400	1190	1320	297	283	290	13.8	2130	1580	1860	1900	1400	1650	-	-	
12/80	4.1	4.1	4.1	1360	1050	1200	274	264	269	13.4	2230	1670	1950	2210	1650	1930	-	-	
1/81	5.3	4.1	4.6	1260	1020	1150	292	289	289	10.3	1960	1720	1850	1800	1620	1710	7.2	4.1	6.7
2/81	4.6	3.1	3.9	1460	1260	1370	302	285	294	16.8	2200	1500	1900	2000	1370	1710	11.5	7.8	
3/81	4.3	3.1	3.5	1730	1170	1320	294	278	287	16.0	1910	1490	1760	1750	1490	1670	10.6	5.9	7.9
4/81	5.2	3.6	4.2	1380	1090	1250	304	283	293	22.5	1750	1500	1640	1650	1420	1550	7.3	3.8	5.4
5/81				1430	1120	1270	273				2080	1390	1740	1910	1190	1540	9.8	4.9	8.2
6/81				1470	1090	1280													
7/81	5.9	4.6	5.1	1420	1200	1320	304	268	292	23.0	2110	1730	1970	2110	1720	1900	6.9	3.4	5.0
8/81	7.2	5.5	6.1	1500	1240	1370	319	292	306	26.6	2240	1560	1900	2210	1350	1790	6.3	2.9	2.9
9/81	8.5	7.0	7.8	1480	1220	1350	312	286	300	28.5	2250	1700	1970	2270	1670	1970	7.1	4.3	5.3
10/81	6.9	5.9	6.4	1460	1140	1300	310	285	299	27.6	2090	1580	1800	2160	1600	1840	9.5	4.2	7.0
11/81	8.1	7.1	7.6	1380	1220	1300	313	278	296	35.0	2220	1330	1800	2280	1370	1820	7.9	4.7	7.4
12/81	7.1	6.3	6.7	1500	1230	1370	297	277	294	37.0	2230	1650	1940	2280	1580	1940	12.9	7.3	9.9
1/82	10.0	8.3	9.1	1510	1200	1360	311	278	295	33.0	2160	1660	1890	2150	1570	1860	10.4	4.7	7.1
2/82	7.9	7.8	7.9	1700	1220	1430	307	284	295	22.8	2140	1700	1920	2120	1550	1880	6.5	3.4	4.9
3/82	9.8	8.9	9.4	1570	1270	1420	321	295	308	26.7	2240	1670	1950	2210	1650	1930	10.7	6.4	8.6
4/82	7.1	3.8	5.4	1550	1410	1480					2240	1470	1860	2230	1480	1860	7.9	1.8	4.8
5/82	8.9	3.7	6.3	1400	1330	1380	324	297	310	26.0	2240	1400	1820	2120	1320	1740	6.4	0.4	3.4
6/82																			
7/82	8.1	3.5	5.8	1380	1170	1270	319	293	306	26.0	1950	960	1450	1950	1000	1480	13.0	1.4	7.2
8/82	9.0	4.7	6.9	1470	1240	1360	323	296	310	27.0	2210	1290	1760	2110	1240	1690	16.6	2.5	9.6
9/82	8.7	3.9	6.3	1470	1260	1370	314	287	301	26.5	2220	1030	1630	2130	1040	1590	15.5	3.4	9.4

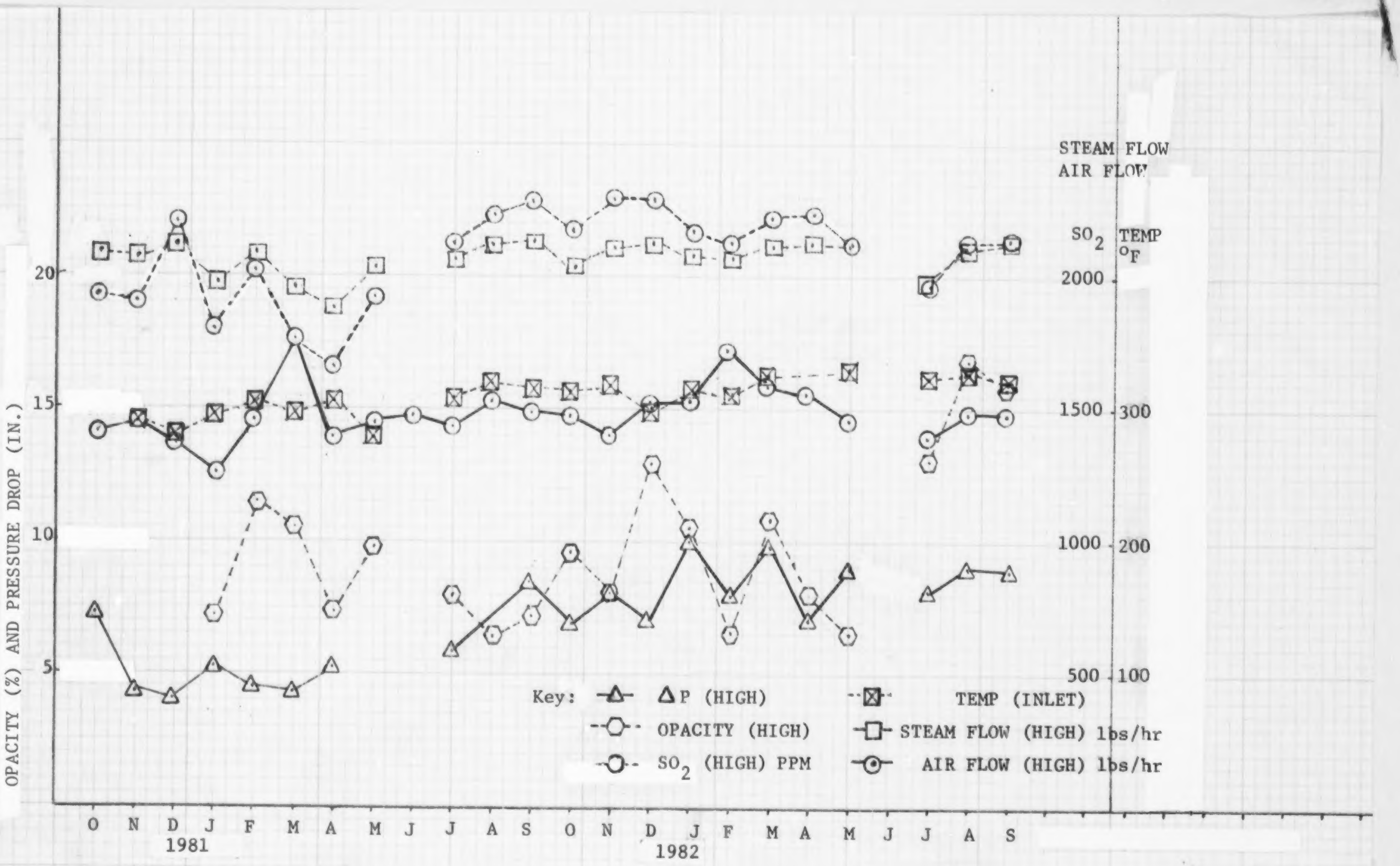


Figure 13. Overview Of Unit Performance Over 24 Months

PP&L has attempted to correct the high pressure drop problem by changing the cleaning cycle, increasing the flow of reverse air, manually cleaning the bags on an intermittant basis and by installing sonic horns. Eight (8) air horns were placed in compartment 7A in November, 1981. Initial data indicate that the horns improved gas flow through this compartment approximately 30%. As a result, plans were made to install air horns in the other 23 compartments by January 1983.

As part of this contract, data in the form of daily averages were collected for the following operating parameters: pressure drop, SO_2 concentration, baghouse inlet and outlet temperatures, steam flow, air flow and stack opacity. These data were recorded by examining strip charts for each day of operation over the 24-month period. These operating data were then graphed, enabling various parameters to be charted over time, such as pressure drop vs. time, opacity vs. time, and number bag failures vs. time. Other graphs were created that charted one parameter against another, for example, percent opacity vs. major events and pressure drop vs. percent opacity.

While gathering these data, notes were made when information was available as to why the data may have varied from normal operating data. Reasons for boiler downtime were documented whenever possible. In addition, a detailed bag failure chart was created and maintained by PP&L. From this chart, it is possible to determine the location of each bag that has failed in every baghouse compartment, number of multiple failures, reason for failure, and failure dates.

It does not appear from examining Figure 13, that the baghouse inlet temperature drops significantly during periods of high pressure drop. However, the data from Table 3 show that on several occasions, a month in which the pressure drop was high was usually preceded by a month in which the inlet temperature and the resulting outlet temperature fell below some critical point. For example, in December 1980, the average inlet temperature was approximately 274°F, and the average outlet temperature 269°F. In the following month, January 1981, the pressure drop increased to 5.3 in. of H_2O, from the previous month's value of 4.1 Other months of low temperature followed by months of increased pressure drop include 3/81 - 4/81, 7/81 - 8/81, and 12/81 - 1/82. These low temperatures in the baghouse may have allowed the flue gas to reach its dew point. If this occurred, sulfuric acid (in the flue gas) would condense on the fabric, creating wet surfaces on the bags where particles would collect. After drying, the particles would then be difficult to remove by using the normal bag cleaning techniques. Consequently, the pressure drop would likely increase as the PP&L maintenance crew observed.

As can be seen in Figure 14, inlet and outlet temperatures remained fairly consistent over the two year span. Some increase in temperatures occurred during the 1981-82 winter. Fluctuations in monthly average inlet temperature ranged from $2^{O}F$ to $31^{O}F$. Fluctuations in monthly average outlet temperatures ranged from $1^{O}F$ to $25^{O}F$.

Monthly average high SO_2 concentrations were in the range of 1400-1500 PPM with the exceptions of March of 1981 and February of 1982, when sudden increases occurred. The highest average monthly SO_2 concentration was 1737 PPM in March 1981. Average monthly high SO_2 concentrations rose again to 1704 PPM in February 1982 (See Figure 15).

The average monthly high opacity varied considerably from start-up (October 1980) through November, 1981, ranging from 4.5 percent to 11.5 percent, and fluctuating monthly. In December of 1981, average monthly high opacity skyrocketed from approximately 8 percent to almost 13 percent (See Figure 16). This significant increase in opacity can be correlated with a rash of bag failures (55 in December) (See Figure 17), many catastrophic in nature. Opacity then began to taper off to a 1982 low of 6.5 in February before beginning another upturn the following March. The highest opacity read during the 24 month recording period was observed in August of 1982 (16.6 percent), a month in which a high number of bags were

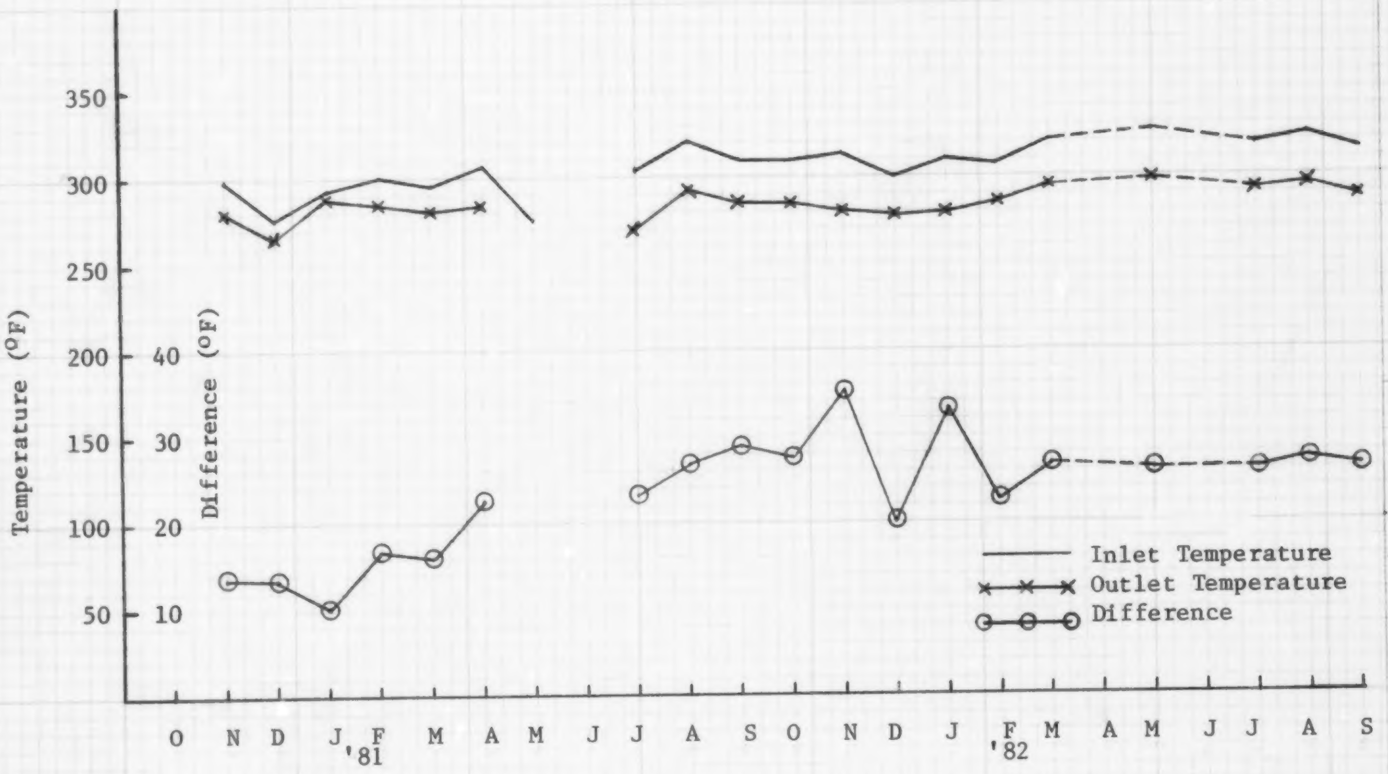


Figure 14. Baghouse Temperature History

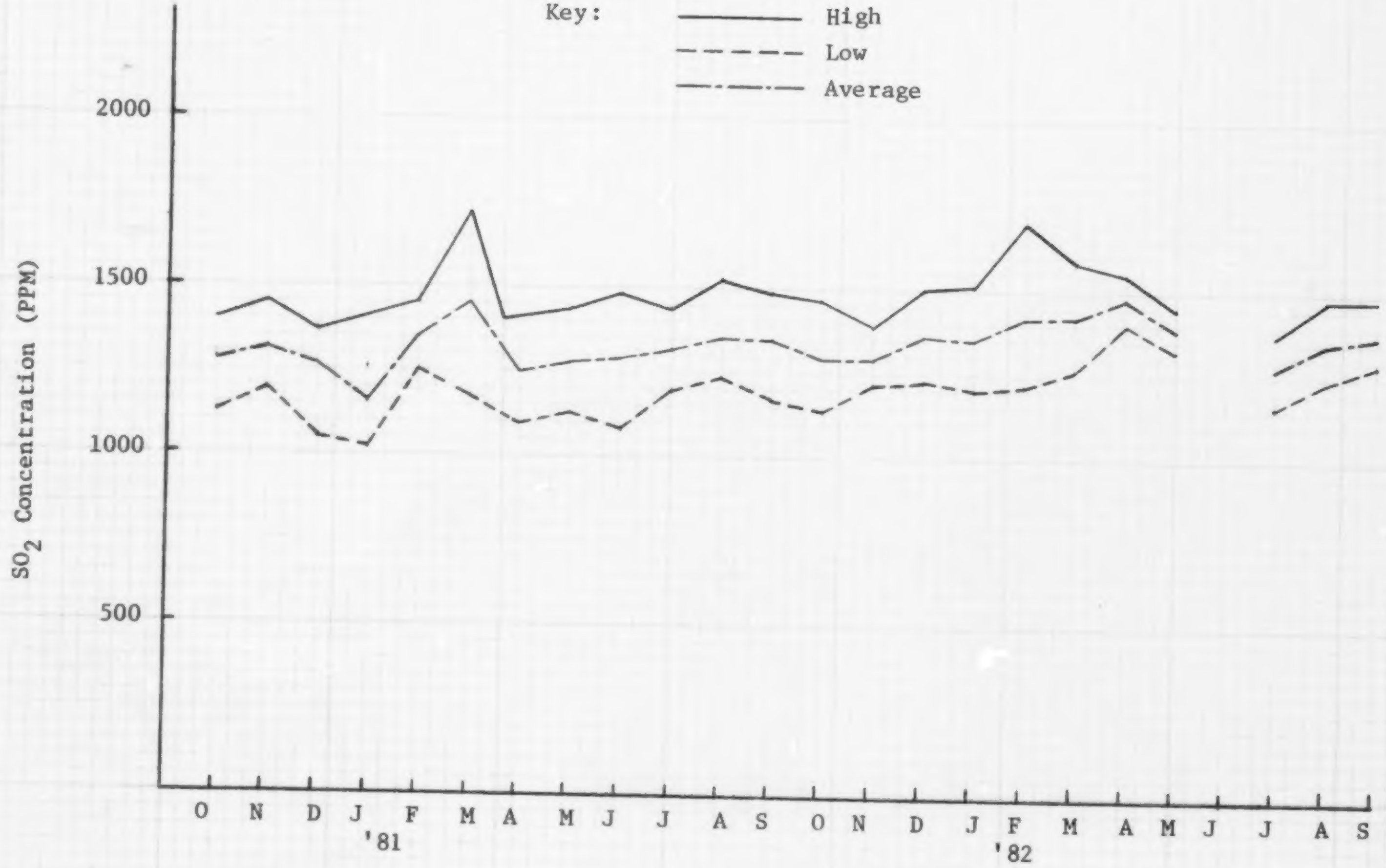


Figure 15. Sulfur Dioxide Concentration

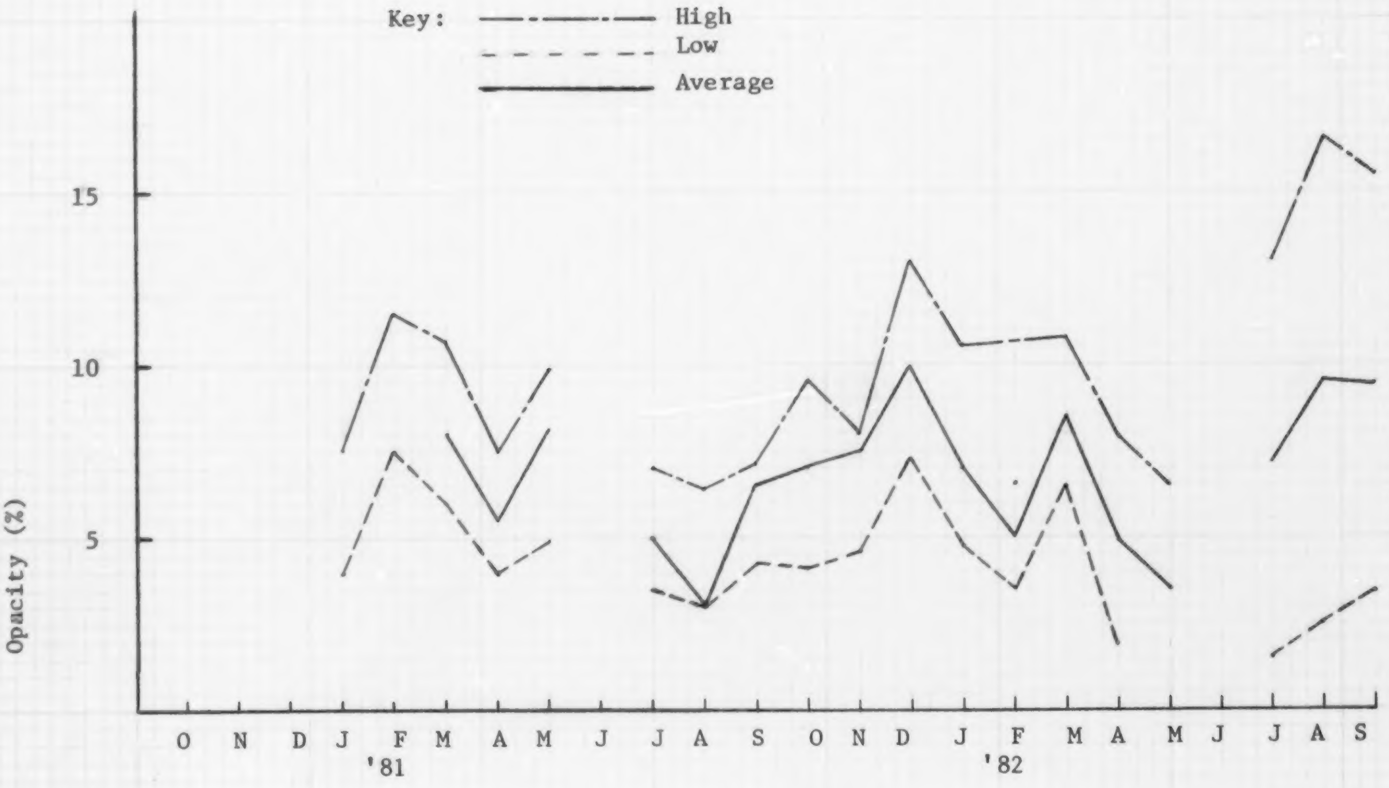


Figure 16. Opacity Readings (24 months)

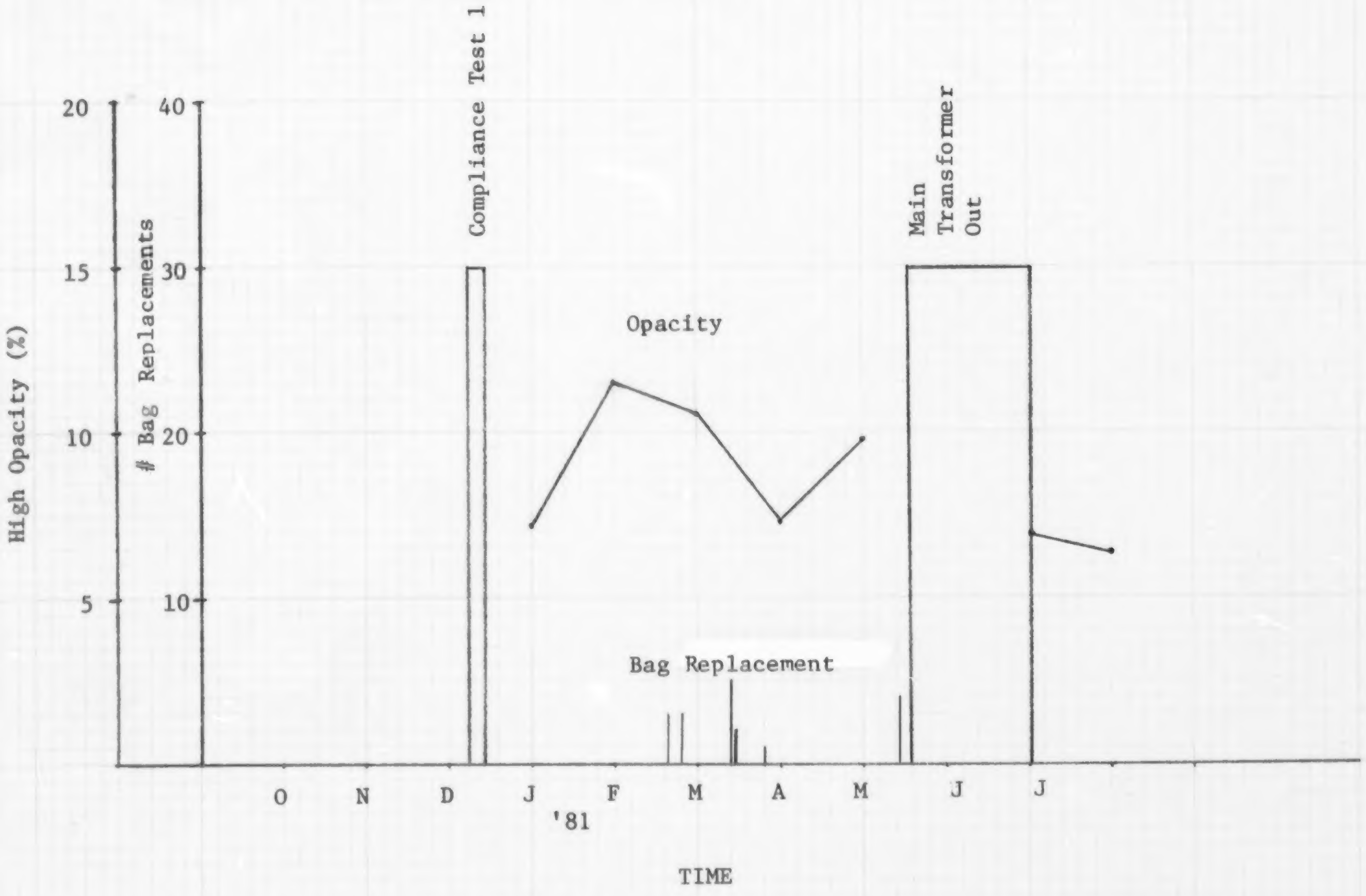


Figure 17 (Pt. 1). Bag Replacement and Opacity History

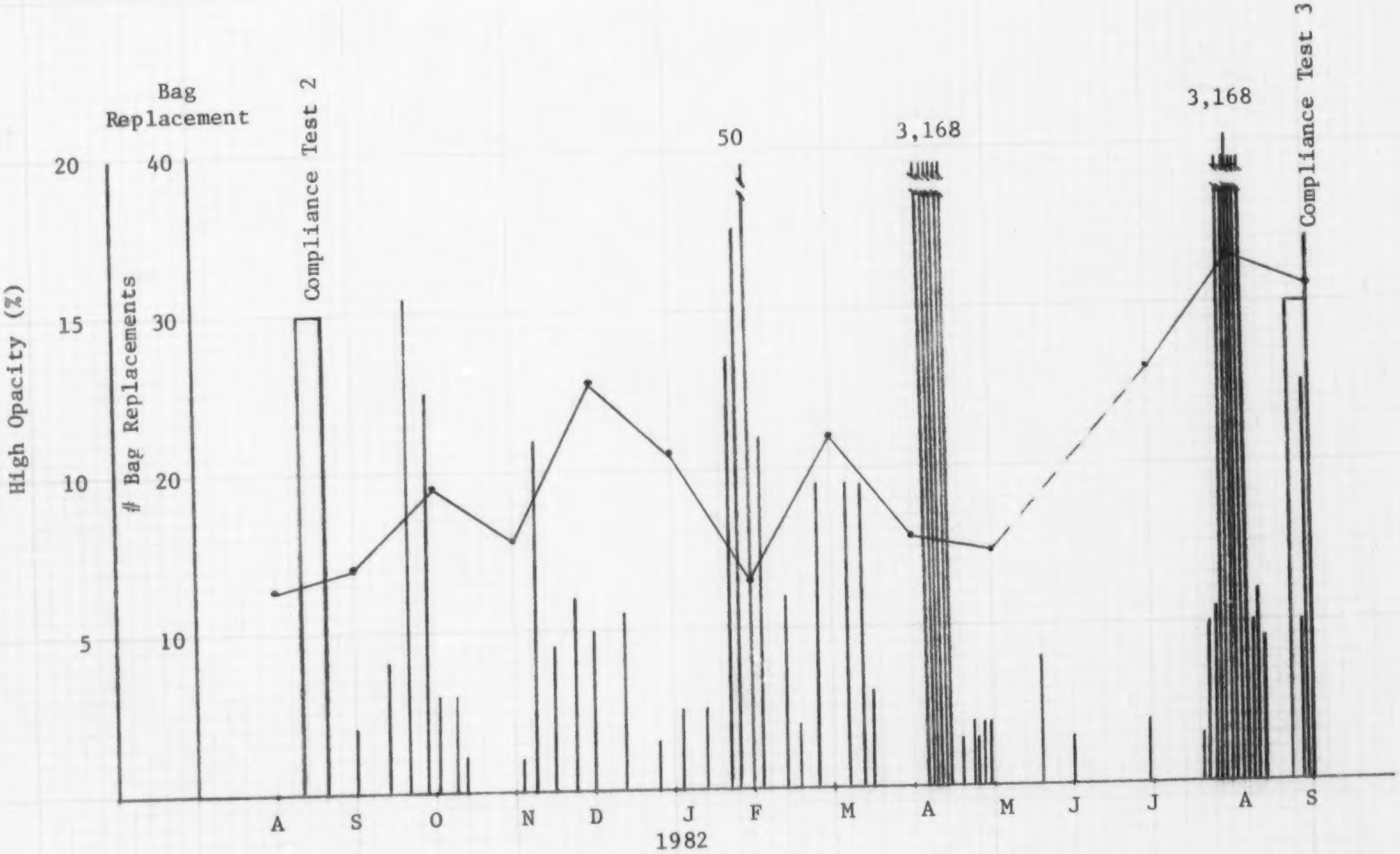


Figure 17 (Pt. 2). Bag Replacement and Opacity History

replaced. It should be noted that this was the second performance tests that were done in September. It was noticed that in some cases increases in opacity lagged behind increases in pressure drop. Pressure drop could possibly be a precursor to bag failure for this unit.

Average daily opacity was charted for five randomly selected "typical" days (See Figure 18). This produced five totally different patterns for each day. It should be noted that opacity was recorded at different times each day.

The number of bag failures remained somewhat consistent through September of 1981. A dramatic increase in bag failures occurred in October of 1981 and continued at approximately the same rate through January of 1982. The following month (February, 1982) bag failures rose significantly. Nearly 150 bag failures occurred in February alone compared to a total of approximately 230 total failures since start-up (15 months). This failure mode continued through the following April, leveling off somewhat through the months of May and June before rising again in July and continuing through the remainder of the recording period (See Figure 19). This skyrocketing failure mode necessitated one complete bag set changeout of the entire baghouse. This changeout occurred in two stages during the months of April and August of 1982.

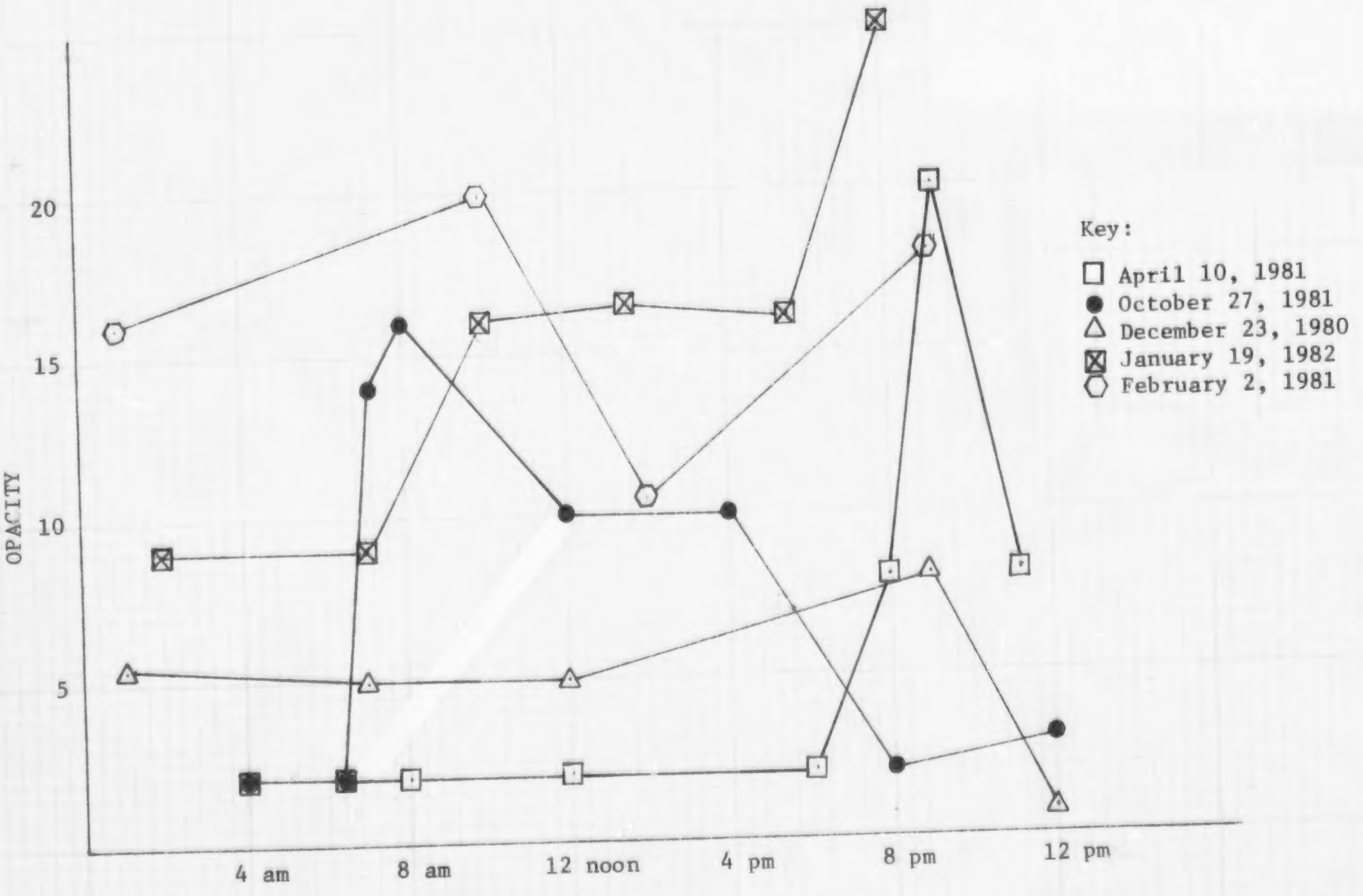


Figure 18. Opacity -5 Typical Days

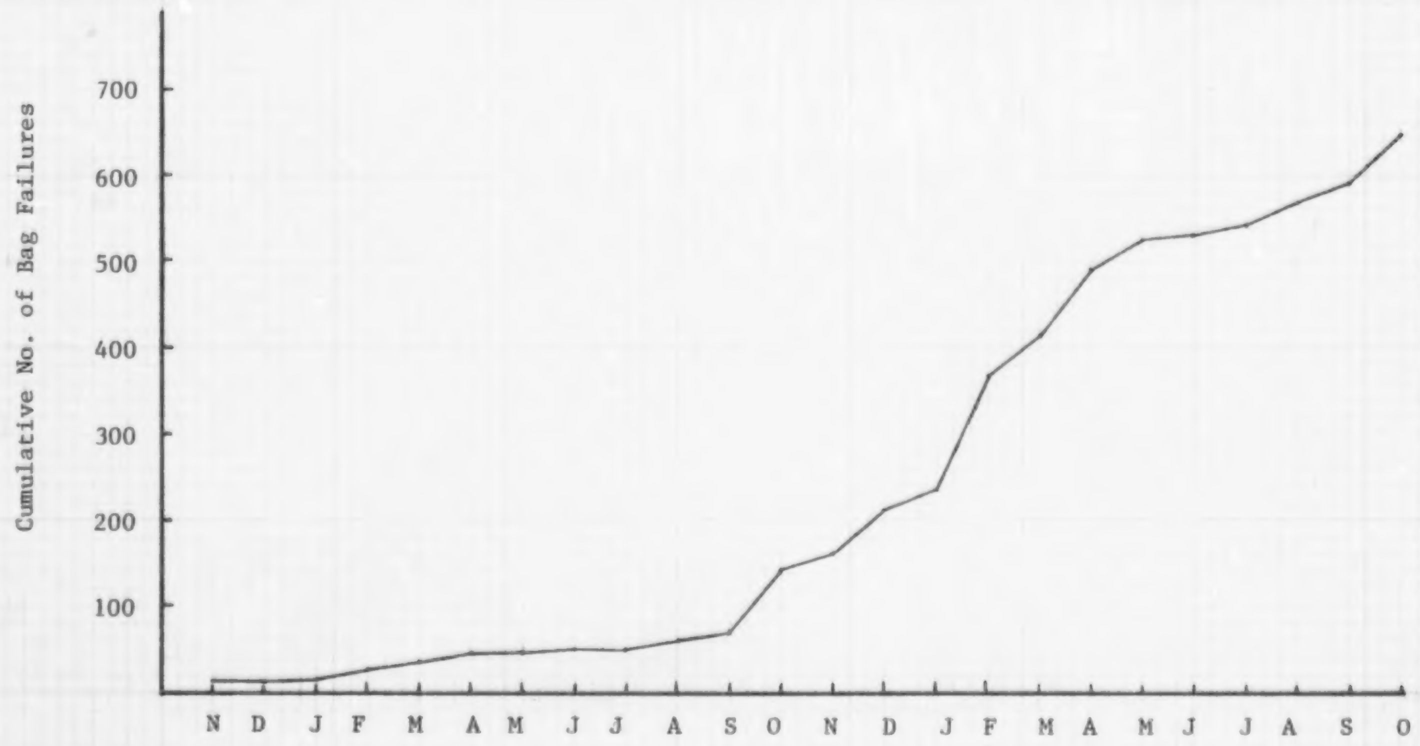


Figure 19. Bag Failure History

The most common reason for bag failure was large holes in the bags greater than two inches in diameter. Some of these large holes took the form of elongated rips or tears, sometimes measuring three to four feet in length. The majority of the other large holes measured two to six inches in size. According to PP&L personnel, the exact cause of each failure was nearly impossible to determine, but a significant number of these large holes were caused by improper bag tensions. This problem coupled with bag weights approaching 100 pounds and an inability to effectively clean the bags resulted in the increasing and excessive residual dust cake.

Many large holes appeared to have been caused by one bag failing first, then creating a "domino effect" where the bags surrounding the first bag later failed in a similar manner.

The majority of other bag failures was attributed to holes less than two inches in diameter and pinholes (see Figure 20). It appears that most of the pinholes occurred near the cuff and thimble.

As can be seen from Figure 21, the greatest number of bag failures occurred in the first four compartments of A and B. More than twice as many failures occurred in the B compartments than occurred in the A compartment (940 vs. 227). The greatest number of failures occurred in compartment 4B followed closely by compartment 3B. A diagram showing the location of bag compartments may be found in Figure 22.

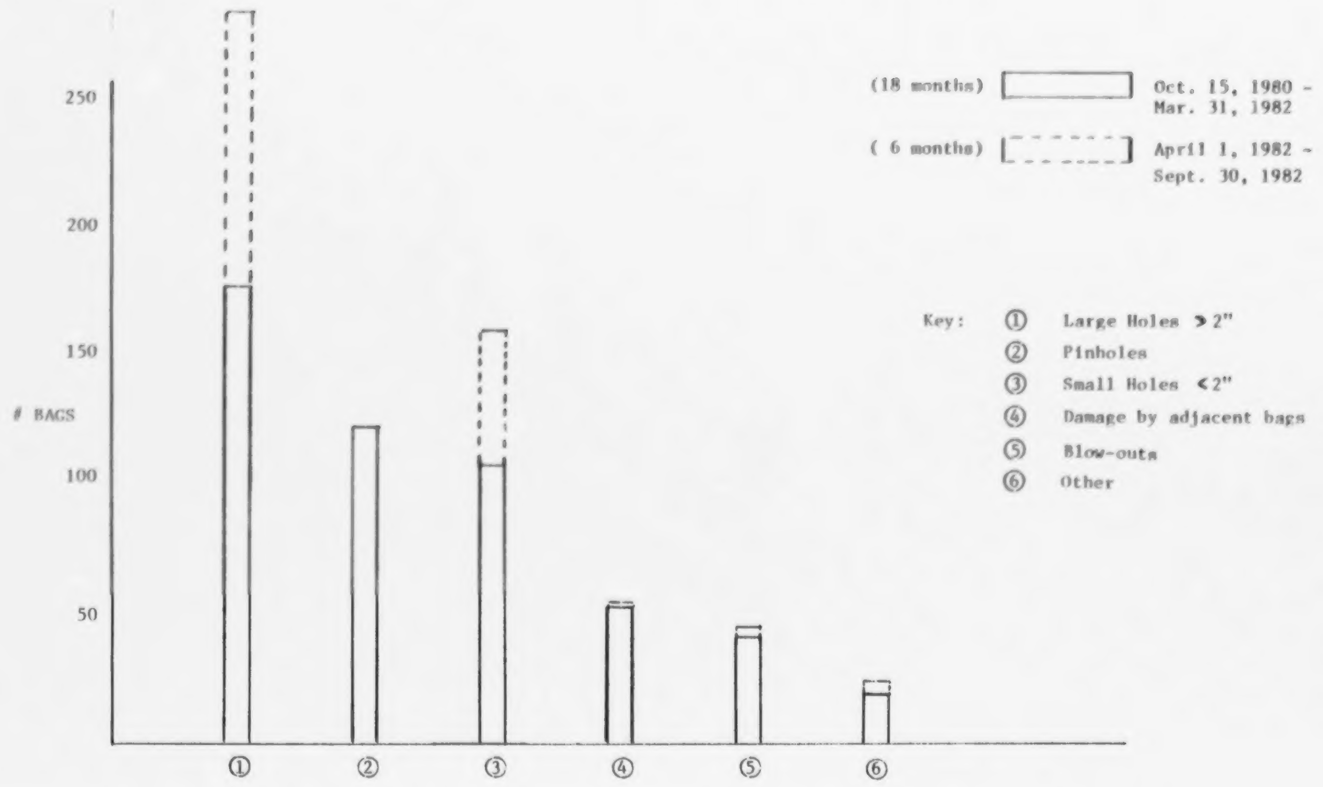


FIGURE 20. BAG FAILURE MODE

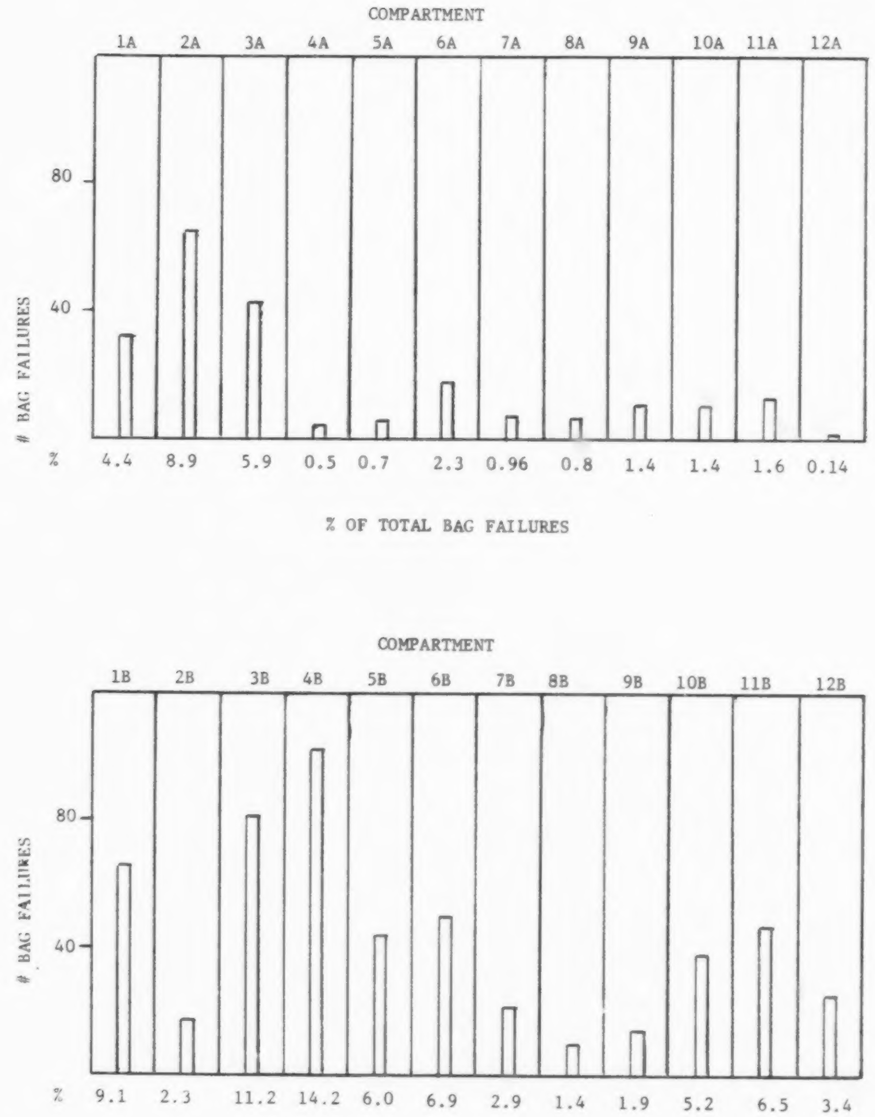


FIGURE 21. % OF TOTAL BAG FAILURES OCCURRING BETWEEN OCTOBER 15, 1980 AND SEPTEMBER 30, 1982.

FIGURE 22

BAGHOUSE COMPARTMENT DIAGRAM
PP&L

BRUNNER ISLAND STATION

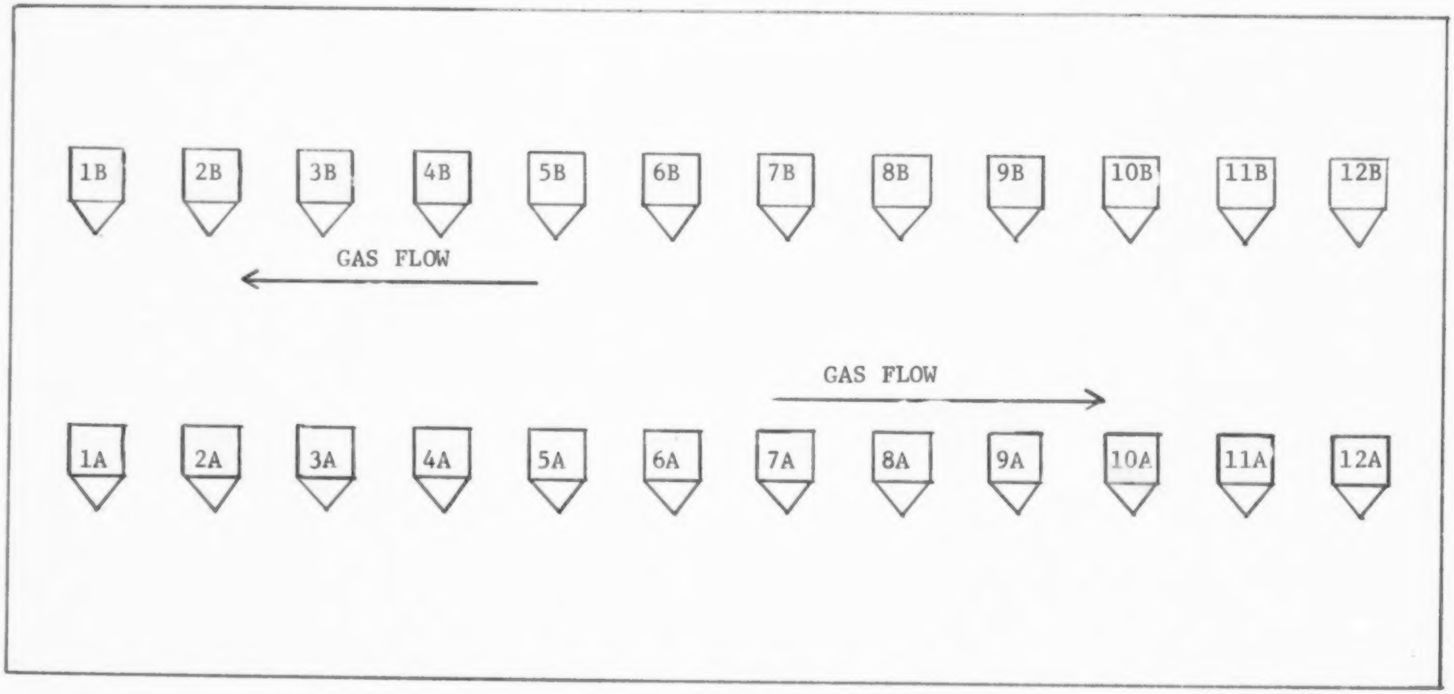

1B
2B
3B
4B
5B
6B
7B
8B
9B
10B
11B
12B
GAS FLOW
GAS FLOW
1A
2A
3A
4A
5A
6A
7A
8A
9A
10A
11A
12A

TABLE 11. BAG TESTING - LAB RESULTS

TESTING CO. & BAG I.D.	EXPOSURE (MONTHS)	TEST DATE	FLEX (FILL) No.toFail	BURST PSI Units	TENSILE		PERMEABILITY	
					Fill lb/in.	Warp lb/in.	Rec'd $Ft^3/Min/Ft^2$	Vac. FPM
ETS/81-195	New	9/2/81	6,733	490	146	360	32.2	
ETS/81-196	New	9/2/81	4,207	554	215	350	62.7	
Tex Lab/	New			609	230	447	53.9	
Tex Lab/#73	7	7/23/81		393	147	188	3.3	13.2
Tex Lab/#96	7	7/23/81		398	151	193	2.8	12.4
ETS/81-198	10	9/2/81	420	323	114	197	4.4	19.8
ETS/81-200	10	9/2/81	294	325	112	189	2.9	19.2
ETS/81-197	10	9/2/81	332	327	112	189	4.0	22.0
Tex Lab/#32	10	3/8/82		332	163	316	3.5	15.6
Tex Lab/#54	10	3/8/82		404	186	314	3.5	13.8
Tex Lab/#76	10	3/8/82		241	85	246	3.5	8.8
Tex Lab/#194	10			228	133	292	3.6	19.4
ETS/#260	14	6/4/82	305		121	228	4.8	25.9
ETS/#261	14	6/4/82	422		120	197	5.0	22.4
Tex Lab/#184	16	3/19/82		205	88	227	3.4	23.8

By far, most A compartment bag failures occurred in compartments 1A, 2A, and 3A, and most of these occurred in modules closer to the system inlet (See Figure 21).

Fabric tests were conducted on four (4) separate occasions by two (2) different testing companies (See Table 11). Fabric tests performed included: tensile strength, permeability, Mullen Burst and MIT Flex text.

The results obtained on the MIT Flex machine are provided in Table 11. The average number of flexes to failure rates on the new bag are in the 4000 to near 7000 range. This is not unusual for this bag type. Testing of bags after ten months exposure indicates that flexes to failure are now approximately in the 300 to 400 range which is greater than a 90% loss of flex strength. After fourteen months, the flexes to failure are still showing the same 300 to 400 range. While this is a relatively low level, it may be that the bags will continue to be of service for an extended period. Continued monitoring is needed to verify if this strength measurement remains in the 300 to 400 range or if it declines further. A drop below 200 flexes would be considered a significant further reduction and more frequent testing would be needed to determine the future of these bags.

Mullen Burst results obtained in the ETS lab indicate that after 10 months exposure more than 60% of the burst strength remains. This is considered satisfactory. The Tex lab results show approximately 40% to 50% burst strength remaining after 10 months exposure and about 34% remaining after 16 months. It should be noted that the single bag tested after 16 months had been cleaned with reverse air and sonic horns whereas bags with less exposure were cleaned with reverse air only.

Tensile strength tests indicate that the new bags had fill flex values ranging from 146 lbs/in to 230 lbs/in. After 14 months exposure, the ETS lab results indicated more than 50% strength remaining while Tex Labs had a few cases (10 and 16 months) where less than 40% strength remained.

The permeability values indicate that the new bags have a range of about 30 to 60 whereas the bags "as received to the lab" show a permeability range of 2.8 to 5.0. This latter value is not considered unusual for bags that have been used in baghouses installed on coal-fired boilers. The permeability of the fabric after being vacuumed even up to 30" w.g. indicates that probably less than 50% of the original permeability value is obtained. This indicates that dust lodged in the fabric may be relatively difficult to remove.

In addition to the tests previously mentioned, a Loss of Ignition (LOI) test was performed on the two new bags to verify the amount of organic coating present. These results indicated 10.6% LOI which corresponds well with the 10% Teflon coating specified.

The overview of these lab results indicates that while the burst and tensile strength are no indication of potential problems, the flex results do raise a flag and indicate that a large percentage of flex strength has been lost. Any further deterioration in flex strength would be a cause for alarm and possibly be an indicator of numerous potential bag failures. The permeability values of "as received" bags do not look unusual, however, the recovery of the permeability after 30" vacuum is poor and may be an indicator of the cause of increased pressure drop because of dust being lodged in the fabric interstices. Once this happens it is very difficult to remove the dust by using conventional bag cleaning techniques.

REFERENCES

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2) Murray, R. W. and G. L. Lear. Design, Start-up and Operation to Date of the Brunner Island - Unit I Bag Filter. Proceedings, Pennsylvania Electric Association. Power Generation Committee Meeting. January 21, 1982.

3) Wagner, M. H. Current Status of Bag Filters at Pennsylvania Power and Light Company. Proceedings, Third International Fabric Alternatives Forum. September 20, 1978.

4) Lear, G. L., Pennsylvania Power and Light Company Brunner Island Unit I Bag Filter Operating and Maintenance Problems. Proceedings, 76th APCA Annual Meeting and Exhibition in Atlanta. June 20, 1983.

APPENDIX 1

Btu Heat Input Calculations

BRUNNER ISLAND S.E.S.

UNIT NO. 1

HEAT INPUT CALCULATIONS

RUN 1

Take data from Control Room Sheets

1.	Steam leaving Superheater	1003 °F	
2.	Steam Pressure	2378 psig	2393 psia
3.	Main Steam Flow	2250 K lb/hr	
4.	BFW Leaving #7 Heater Temperature	472 °F	
5.	BFW Leaving #7 Heater Pressure	2722 psig	2737 psia
6.	Cold Reheat Pressure	567 psig	582 psia
7.	Water Leg	---- H_2O	
8.	Cold Reheat Temperature (Turb. Cold Reheat out)	630 °F	
9.	Hot Reheat Pressure	492 psig	507 psia
10.	Hot Reheat Temperature (Tub. Hot Reheat In)	1008 °F	
11.	Barometric Pressure	29.60 in. Hg	14.54 psia
12.	Reheat Steam Flow	2050 From Graph (Attached)	

I. Convert barometric pressure reading to psia by using density of mercury at temperature of the barometer.

II. Convert all pressure readings from psig to psia by adding the barometer reading in psia to the pressure reading. For BFW Pressure, add the water leg also.

III. Find the following enthalpies:

H_{MS} - Enthalpy of Main Steam at (1) °F and (2) psia 1462 BTU/lb

H_{FW} - Enthalpy of Feedwater at (4) °F and (5) psia 464 BTU/lb

H_{CRH}- Enthalpy of Cold Reheat at (8) °F and (6) psia 1310

H_{HRH}- Enthalpy of Hot Reheat at (10) °F and (9) psia 1524

IV. Calculate the boiler heat input using the following equations:

$$\frac{BTU}{Hr} = \frac{(\text{Main Steam Flow})\ (H_{HS} - H_{FW}) + (\text{Reheat Flow})\ (H_{HRH} - H_{CRH})}{(\text{Boiler Efficiency})}$$

Boiler Efficiency = .852

For enthalpies, use Kennan and Keyes Edition of Steam Tables.

$$\frac{\frac{BTU}{in} = (2.250 \times 10^6\ \frac{lb}{in})\ (1462-464) = 2050 \times 10^6\ (1524-1310)}{.852} = \frac{BTU}{in} = 3.15 \times 10^9$$

BRUNNER ISLAND S.E.S.

UNIT NO. 1

HEAT INPUT CALCULATIONS

RUN 2

Take data from Control Room Sheets

1.	Steam leaving Superheater	1011 °F	
2.	Steam Pressure	2400 psig	2415 psia
3.	Main Steam Flow	2251 K lb/hr	
4.	BFW Leaving #7 Heater Temperature	474 °F	
5.	BFW Leaving #7 Heater Pressure	2713 psig	2728 psia
6.	Cold Reheat Pressure	579 psig	594 psia
7.	Water Leg	---- H_2O	
8.	Cold Reheat Temperature (Turb. Cold Reheat out)	640 °F	
9.	Hot Reheat Pressure	500 psig	515 psia
10.	Hot Reheat Temperature (Tub. Hot Reheat In)	1018 °F	
11.	Barometric Pressure	29.69 in. Hg	14.59 psia
12.	Reheat Steam Flow	2050 From Graph	(Attached)

I. Convert barometric pressure reading to psia by using density of mercury at temperature of the barometer.

II. Convert all pressure readings from psig to psia by adding the barometer reading in psia to the pressure reading. For BFW Pressure, add the water leg also.

III. Find the following enthalpies:

H_{MS} - Enthalpy of Main Steam at (1) °F and (2) psia 1466 BTU/lb

H_{FW} - Enthalpy of Feedwater at (4) °F and (5) psia 464 BTU/lb

H_{CRH} - Enthalpy of Cold Reheat at (8) °F and (6) psia 1315

H_{HRH} - Enthalpy of Hot Reheat at (10) °F and (9) psia 1556

IV. Calculate the boiler heat input using the following equations:

$$\frac{BTU}{Hr} = \frac{(\text{Main Steam Flow})\ (H_{HS} - H_{FW}) + (\text{Reheat Flow})\ (H_{HRH} - H_{CRH})}{(\text{Boiler Efficiency})}$$

Boiler Efficiency = .852

For enthalpies, use Kennan and Keyes Edition of Steam Tables.

$$\frac{\frac{BTU}{in} = 2251 \times 10^6\ (1466-464) + 205 \times 10^6\ (1556-1315)}{.852} = 323 \times 10^9$$

BRUNNER ISLAND S.E.S.

UNIT NO. 1

HEAT INPUT CALCULATIONS

RUN 3

Take data from Control Room Sheets

1. Steam leaving Superheater 1009 °F
2. Steam Pressure 2399 psig 2414 psia
3. Main Steam Flow 2250 K lb/hr
4. BFW Leaving #7 Heater Temperature 474 °F
5. BFW Leaving #7 Heater Pressure 2721 psig 2736 psia
6. Cold Reheat Pressure 569 psig 584 psia
7. Water Leg ---- H_2O
8. Cold Reheat Temperature (Turb. Cold Reheat out) 637 °F
9. Hot Reheat Pressure 495 psig 510 psia
10. Hot Reheat Temperature (Tub. Hot Reheat In) 1018 °F
11. Barometric Pressure 29.72 in. Hg 14.60 psia
12. Reheat Steam Flow 2050 From Graph (Attached)

I. Convert barometric pressure reading to psia by using density of mercury at temperature of the barometer.

II. Convert all pressure readings from psig to psia by adding the barometer reading in psia to the pressure reading. For BFW Pressure, add the water leg also.

III. Find the following enthalpies:

H_{MS} - Enthalpy of Main Steam at (1) °F and (2) psia 1466

H_{FW} - Enthalpy of Feedwater at (4) °F and (5) psia 464

H_{CRH} - Enthalpy of Cold Reheat at (8) °F and (6) psia 1315

H_{HRH} - Enthalpy of Hot Reheat at (10) °F and (9) psia 1529

IV. Calculate the boiler heat input using the following equations:

$$\frac{BTU}{Hr} = \frac{(\text{Main Steam Flow})\ (H_{HS} - H_{FW}) + (\text{Reheat Flow})\ (H_{HRH} - H_{CRH})}{(\text{Boiler Efficiency})}$$

Boiler Efficiency = .852

For enthalpies, use Kennan and Keyes Edition of Steam Tables.

$$\frac{BTU}{in} = \frac{(2.25 \times 10^6)\ (1466-464) + 2050 \times 10^6\ (1529-1315)}{.852} = 3.16 \times 10^9$$

BRUNNER ISLAND S.E.S.

UNIT NO. 1

HEAT INPUT CALCULATIONS

RUN 4

Take data from Control Room Sheets

1.	Steam leaving Superheater	1014 °F	
2.	Steam Pressure	2400 psig	2415 psia
3.	Main Steam Flow	2250 K lb/hr	
4.	BFW Leaving #7 Heater Temperature	473 °F	
5.	BFW Leaving #7 Heater Pressure	2719 psig	2734 psia
6.	Cold Reheat Pressure	572 psig	587 psia
7.	Water Leg	----- H_2O	
8.	Cold Reheat Temperature (Turb. Cold Reheat out)	642 °F	
9.	Hot Reheat Pressure	500 psig	515 psia
10.	Hot Reheat Temperature (Tub. Hot Reheat In)	1022 °F	
11.	Barometric Pressure	29.59 in. Hg	14.54 psia
12.	Reheat Steam Flow	2050 From Graph (Attached)	

I. Convert barometric pressure reading to psia by using density of mercury at temperature of the barometer.

II. Convert all pressure readings from psig to psia by adding the barometer reading in psia to the pressure reading. For BFW Pressure, add the water leg also.

III. Find the following enthalpies:

H_{MS} - Enthalpy of Main Steam at (1) °F and (2) psia 1466

H_{FW} - Enthalpy of Feedwater at (4) °F and (5) psia 464

H_{CRH}- Enthalpy of Cold Reheat at (8) °F and (6) psia 1316

H_{HRH}- Enthalpy of Hot Reheat at (10) °F and (9) psia 1556

IV. Calculate the boiler heat input using the following equations:

$$\frac{BTU}{Hr} = \frac{(\text{Main Steam Flow})\ (H_{MS} - H_{FW}) + (\text{Reheat Flow})\ (H_{HRH} - H_{CRH})}{(\text{Boiler Efficiency})}$$

Boiler Efficiency = .852

For enthalpies, use Kennan and Keyes Edition of Steam Tables.

$$\frac{BTU}{in} = \frac{(2.25 \times 10^6)\ (1466-464) + 2.05 \times 10^6\ (1566-1316)}{.852} = 3.22 \times 10^9$$

BRUNNER ISLAND S.E.S.

UNIT NO. 1

HEAT INPUT CALCULATIONS

Take data from Control Room Sheets RUN 5

1.	Steam leaving Superheater	1004 °F	
2.	Steam Pressure	2400 psig	2415 psia
3.	Main Steam Flow	2250 K lb/hr	
4.	BFW Leaving #7 Heater Temperature	473 °F	
5.	BFW Leaving #7 Heater Pressure	2721 psig	2736 psia
6.	Cold Reheat Pressure	566 psig	581 psia
7.	Water Leg	--- H_2O	
8.	Cold Reheat Temperature (Turb. Cold Reheat out)	632 °F	
9.	Hot Reheat Pressure	491 psig	506 psia
10.	Hot Reheat Temperature (Tub. Hot Reheat In)	1016 °F	
11.	Barometric Pressure	29.38 in. Hg	14.43 psia
12.	Reheat Steam Flow	2050 From Graph (Attached)	

I. Convert barometric pressure reading to psia by using density of mercury at temperature of the barometer.

II. Convert all pressure readings from psig to psia by adding the barometer reading in psia to the pressure reading. For BFW Pressure, add the water leg also.

III. Find the following enthalpies:

H_{MS} - Enthalpy of Main Steam at (1) °F and (2) psia 1464

H_{FW} - Enthalpy of Feedwater at (4) °F and (5) psia 464

H_{CRH} - Enthalpy of Cold Reheat at (8) °F and (6) psia 1310

H_{HRH} - Enthalpy of Hot Reheat at (10) °F and (9) psia 1528

IV. Calculate the boiler heat input using the following equations:

$$\frac{BTU}{Hr} = \frac{(\text{Main Steam Flow})\ (H_{HS} - H_{FW}) + (\text{Reheat Flow})\ (H_{HRH} - H_{CRH})}{(\text{Boiler Efficiency})}$$

Boiler Efficiency = .852

For enthalpies, use Kennan and Keyes Edition of Steam Tables.

$$\frac{BTU}{in} = \frac{2.25 \times 10^{6}\ (1464-464) + 2.05 \times 10^{6}\ (1528-1310)}{.852} = 3.17 \times 10^{9}$$

APPENDIX 2

Cascade Impactor Sampling Results

CASCADE IMPACTOR SAMPLING
AT A FABRIC FILTER BAGHOUSE

by

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Roanoke, Virginia 24018

September 1981

SECTION 1

INTRODUCTION

Under the EPA project work requirements, impactor tests were carried out during the week of August 10-14, 1981, at Brunner Island Station, owned and operated by the Pennsylvania Power and Light Company. The objective of these tests was to measure size segregated particulate emissions from the fabric filter baghouses. The impactor samples were collected at the inlet and outlet of the baghouses using MRI inertial cascade impactors.

SECTION 2

IMPACTOR SAMPLING

Impactor sampling provides a size segregated sample of particulate matter contained in the flue gas. MRI inertial cascade impactors were used to aerodynamically size segregate the fine particle samples nominally in the diameter range of 0.5 to 10 μm. The impactor design (see Figure 1) is based on a simple annular arrangement of round jets[1] placed in a circular pattern impinging on annular collectors. There are seven impaction stages with a final filter. The use of collection discs permits flexibility in choice of substrate. For example, either a grease or a filter mat can be used to enhance sample collection and its retention on the substrate.

At the Brunner Island Station, stainless steel discs coated with Apiezon-H grease were used to collect fine particle samples from the stack gases. The collection discs have relatively low tare weights and, thus, are ideal for particle sizing sampling since small weight gains due to sample mass can be accurately weighed. Before sampling, impactor collection discs were prepared at the RTI chemistry laboratory. The presampling preparations included individual disc cleaning with 6N hydrochloric acid and rinsing several times in distilled water, followed by a thorough acetone wash. The discs were allowed to dry and coated using a solution of Apeizon-H grease in toluene (1/2 in. length of grease from the tube in 50 ml toluene). The discs were then placed in a tray and heated in an oven at 300° F for four hours. At the end of this period, the discs were removed, cooled, placed in petri dishes, and desiccated for at least 12 hours before presampling weighing. The backup filter (Reeve Angel 934AH) was conditioned with stack gases for six hours at the Waynesboro facility, desiccated for 12 hours, and weighed before loading it in the impactor.

Typically, the sampling train consisted of an impactor attached to a probe, followed by a series of impingers placed in an ice bath. The first

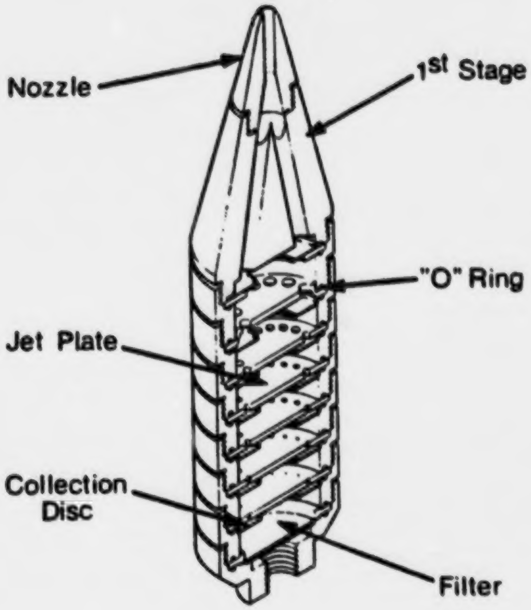
Nozzle
1st Stage
"O" Ring
Jet Plate
Collection Disc
Filter

Figure 1. MRI cascade impactor.

two impingers each contained 100 ml of distilled water. The third impinger was empty and expected to collect carry-over condensables from the flue gas. The fourth impinger had a known weight of silica (approximately 300 g) used for removing moisture from the stack gases and also to protect the pump. The other sampling accessories included pressure and temperature controls and read-outs, a dry gas meter to measure the volume sampled, and, finally, a vacuum pump.

The impactor samples were collected by following a procedure similar to that described by Harris.[2] Since there was a large concentration difference (1000:1) between inlet and outlet, the outlet impactor tests were conducted for four to five hours to obtain enough sample mass to weigh; however, inlet tests were run for only one minute during the outlet tests. Additionally, at the inlet a comparatively smaller flow rate (0.265 acfm) was used to obtain adequate size sample without overloading the impactor stages. Both inlet and outlet impactor samples were collected at a single point inside the stack.

After the sampling, the impactor was removed from the duct, detached from the probe, and allowed to cool. All samples were recovered inside a clean motel room. The impactor was carefully disassembled and collection discs were placed into petri dishes for protection and storage. Sample material collected on the inside walls of the impactor were brushed onto the appropriate collection stages. All samples were desiccated at least 24 hours before determining weight gains using a Perkin-Elmer AD-22 autobalance.

A computer program developed by Denver Research Institute and modified by RTI was used to reduce the size distribution data and generate plots of differential mass distributions and penetrations. Individual data points are not shown since plots show the derivative of an interpolated cumulative size distribution and not the raw data. Particle size distributions are presented as a function of inertial aerodynamic diameter. The particulate collection efficiency of the baghouse is computed by comparison of simultaneous tests at the inlet and outlet. The calculation is made for both total particulate mass and as a function of particle size; the results are expressed as percent penetration. The density of particulate matter was assumed to be 2.4 g/cm^3, a typical value for fly ash. The other parameters needed for impactor data reduction were as follows: water vapor, 7.25 percent; CO_2, 12.13 percent; O_2, 5.60 percent; and CO, 0.1 percent.

SECTION 3

RESULTS AND DISCUSSION

The impactor tests conducted and the mass loading results obtained are shown in Table 1. The primary purpose of impactor tests was to measure differential size distributions and not overall mass loadings.

The inlet size distributions obtained under full boiler load (340 MW) for two sampling days (August 12 and 13, 1981) are included in Figure 2. The results of two inlet tests on two different sampling days agree well.

Bimodal size distributions are commonly observed in the flue gas from a coal-fired boiler.[3 4] The larger mode is considered to be essentially composed of nonvolatile material, while the smaller mode consists of more volatile material that is vaporized during coal combustion and then either homogeneously or heterogeneously condensed.[4] The present distribution data are of a shape similar to the distribution data in the literature; however, because ultrafine measurements Sub.-1.0 um diameter) were not performed, the submocron accumulation particle mode was not resolved.

The outlet size distributions for both sampling days are presented in Figure 3. The particulate concentration at the outlet was nearly 1/1000th of that of the inlet and, hence, sampling times of four hours (August 12, 1981) and five hours (August 13, 1981) were used to collect enough samples on each impactor stage. The inlet and outlet size distributions appear similar in shape except for minor differences in the largest particles at the outlet. The outlet size distribution drops sharply above 10 um apparently because of greater particle collection by the baghouse.

Penetration is the ratio of outlet to inlet and size dependent penetration is obtained by dividing the outlet size distribution by the inlet distribution.

Table 1. Summary of Brunner Island Tests (1981)

Date/location	MMD (μm)	σ_g
8/12/81 Inlet	12.7	1.84
8/12/81 Outlet	6.6	2.12
8/13/81 Inlet	14.0	1.97
8/13/81 Outlet	7.4	2.74
Average inlet	13.4	1.9
Average outlet	7.0	2.4

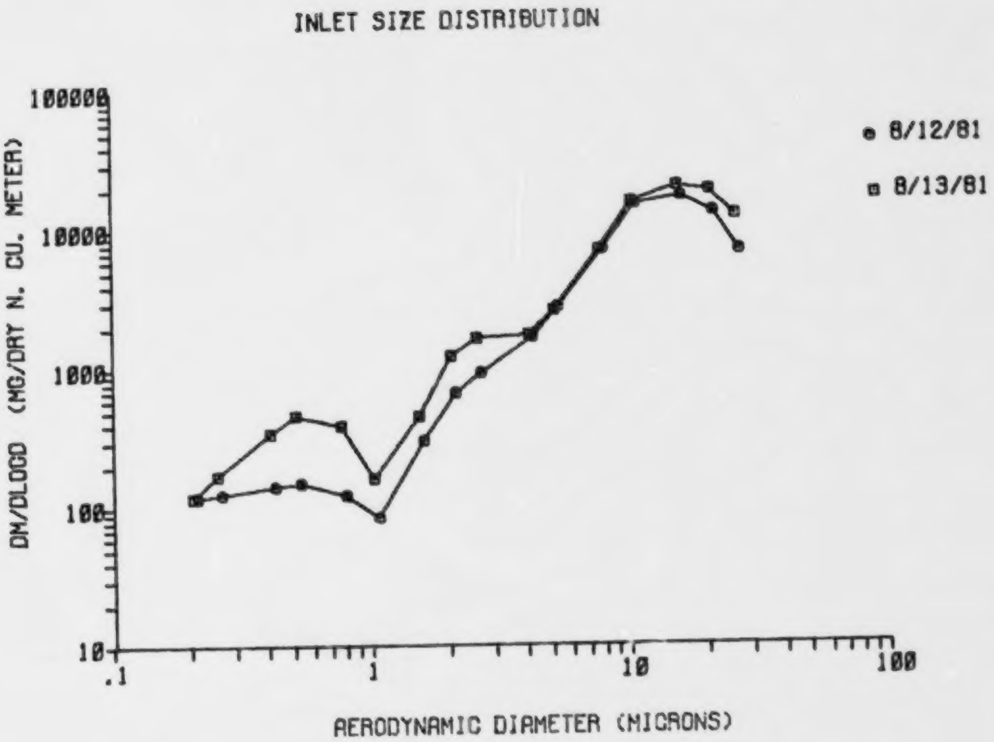

Figure 2. Inlet particle size distribution measured with MRI impactor.

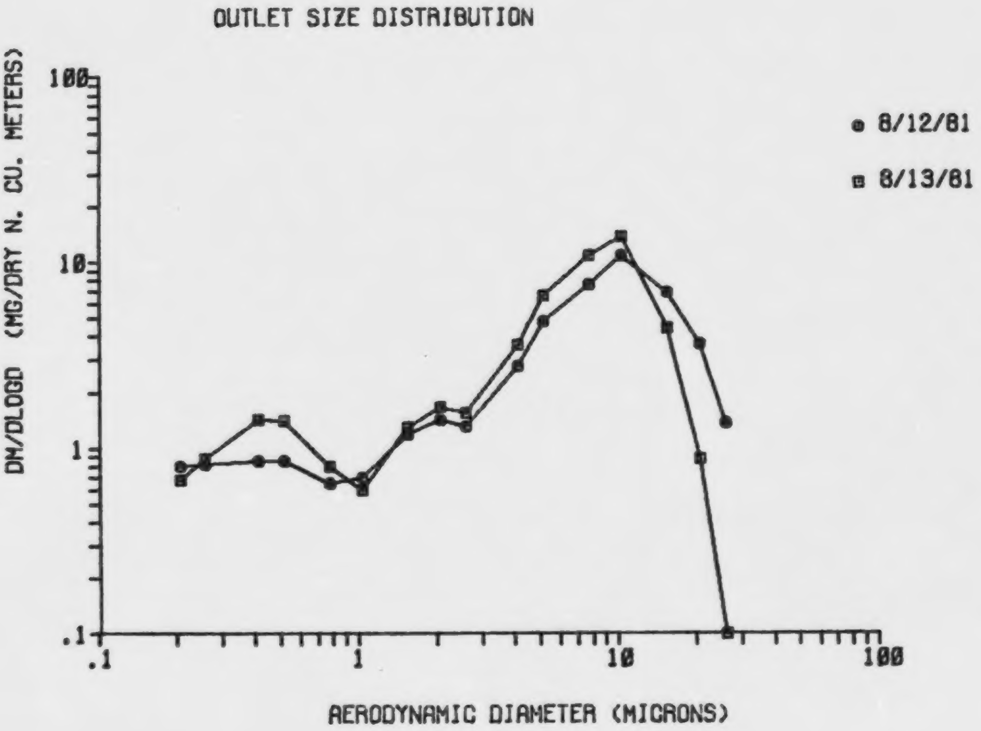

Figure 3. Outlet particle size distribution measured with MRI impactor.

Particle size dependent penetration through the baghouse is shown in Figure 4. The overall penetration (Table 1) was about 0.09 to 0.07 percent. The baghouse collected better than 99.9 percent of the particulate matter from the flue gas. The size dependent penetration indicates that, overall, the baghouse collected larger particles more efficiently than smaller size particles. The penetration curves show two maximums, one peak at 0.9 μm and the other at about 4.5 μm. Similar results were reported by Ensor et al.[3] for a baghouse controlling pulverized coal utility boiler emissions.

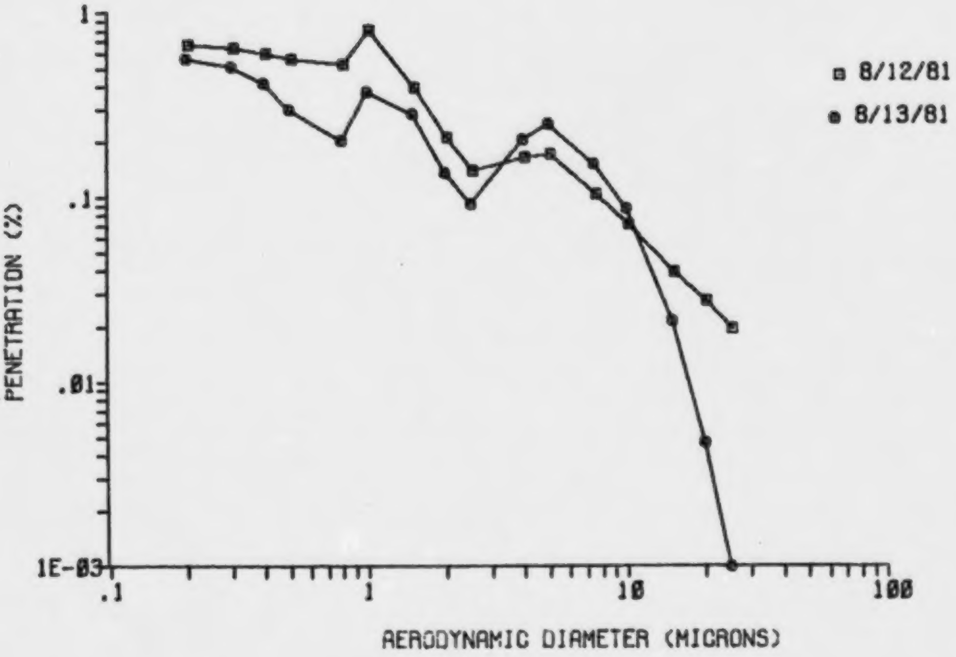

Figure 4. Particle size dependent particulate penetration through the baghouse.

SECTION 4

DATA QUALITY

Quality assurance efforts related to fine particle sampling emphasized substrate preparation, sampling, and sample recovery techniques, and weighing operations. The substrates were prepared at RTI's home laboratory, weighed on two balances (a Perkin-Elmer AD-22 autobalance and a Metler balance), sealed and transported to the test site. Prior to a day of sampling, the required number of substrates were desiccated for at least 12 hours. A standard substrate and substrates for sampling were weighed before loading into the impactor. The loaded impactor was sealed and carried to the testing site. After sampling, the samples were recovered in a clean room at a motel and desiccated for at least 24 hours before weighing. Both the test runs were checked for constant weight over a period of two days. An NBS-traceable weight was used to calibrate the balance and, also, to evaluate the performance of the balance during sample weighing operations.

Two blank tests were run at the outlet. The mean weight gain for the blank run on August 11, 1981, was 0.69 mg with a standard deviation of 0.55 mg. The mean weight gain for a blank on August 14, 1981, was 0.58 mg with a standard deviation of 0.10 mg. The weight gains may have been caused by the collection of condensable components, such as sulfuric acid, from the flue gas.

REFERENCES

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2. Harris, D. B. Tentative Procedures for Particle Sizing in Process Streams: Cascade Impactors. EPA-600/2-76-023, U. S. Environmental Protection Agency, 1976.

3. Ensor, D. S., S. Cowen, A. D. Shendrikar, G. Markowski, and G. Woffinden. Kramer Station Fabric Filter Evaluation. EPRI Report No. 1130-1, Electric Power Research Institute, Palo Alto, California, 1981.

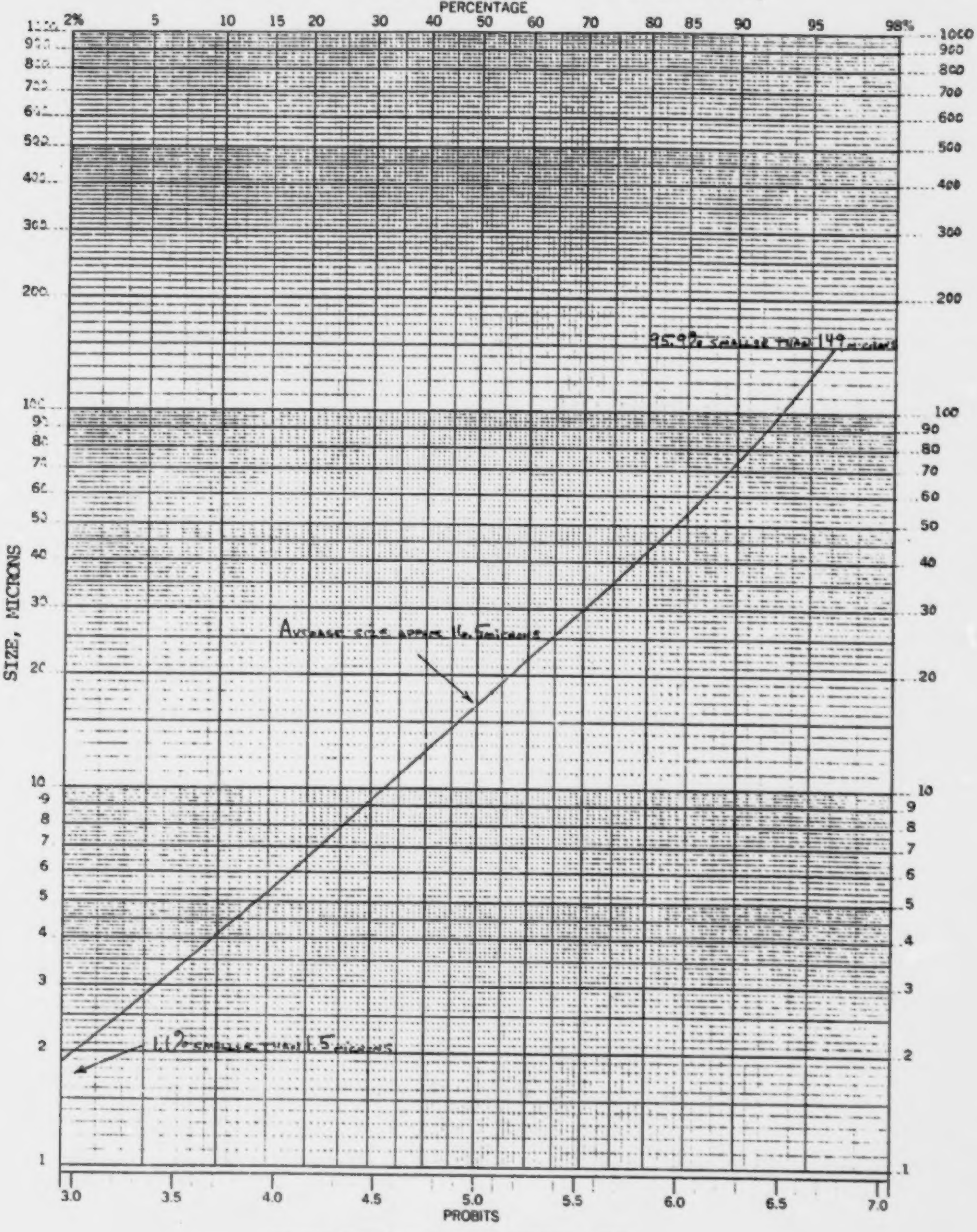
4. Markowski, G. R., D. S. Ensor, R. G. Hooper, and R. C. Carr. A Submicron Aerosol Mode in Flue Gas from a Pulverized Coal Utility Boiler. EST, 14:1400-1402, 1980.

APPENDIX 3

Particle Size Analysis Results

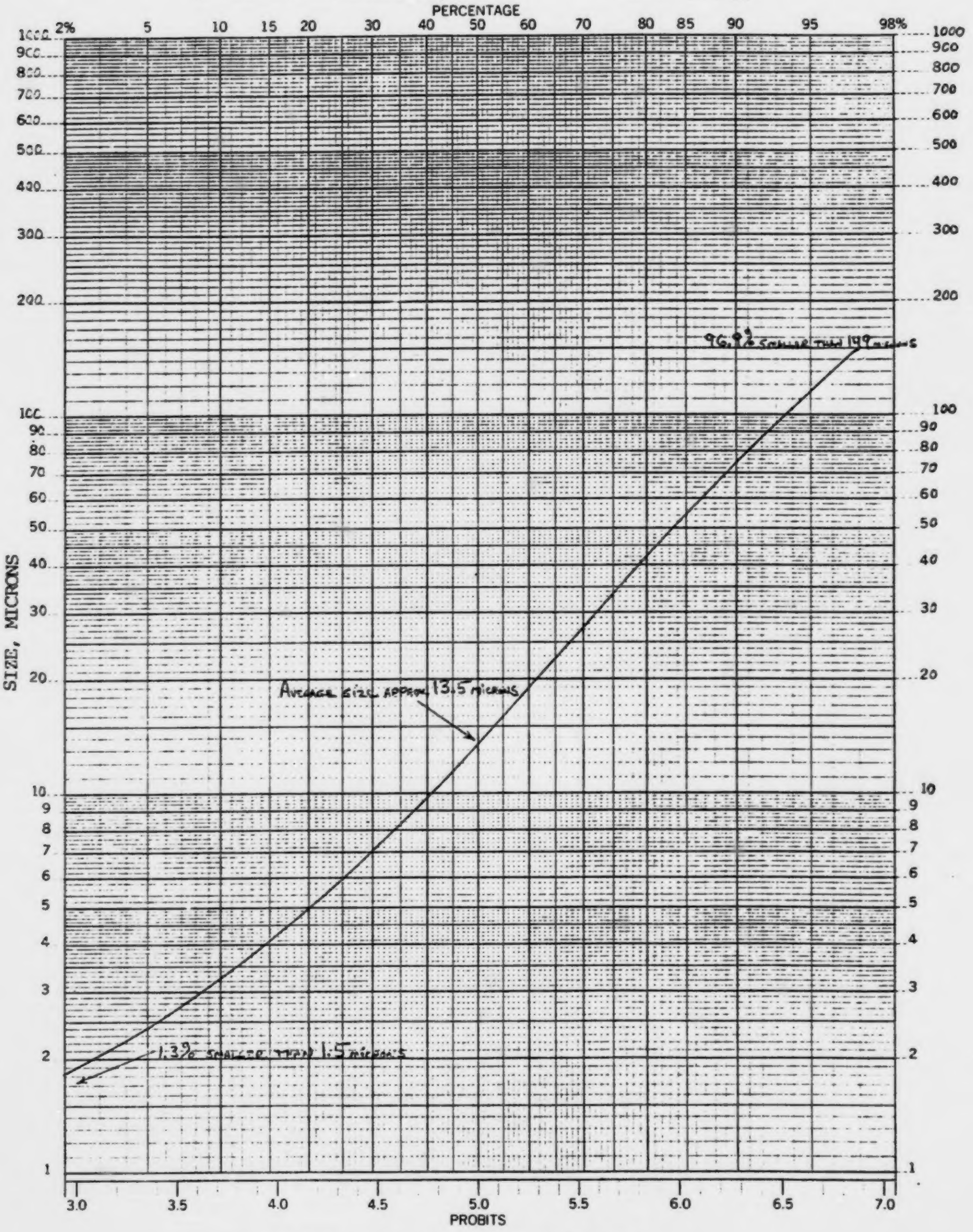
BAHCO ANALYSIS
PARTICLE SIZE DISTRIBUTION

SAMPLE: Run 1 Inlet 8-12-81 2.08g/
COMPANY: ETS
DATE: 9-17-81



SAMPLE: Run 2 Inlet 8-13-81 2.13g
COMPANY: ETS
DATE: 9-17-81

BAHCO ANALYSIS
PARTICLE SIZE DISTRIBUTION



96.9% smaller than 149 microns

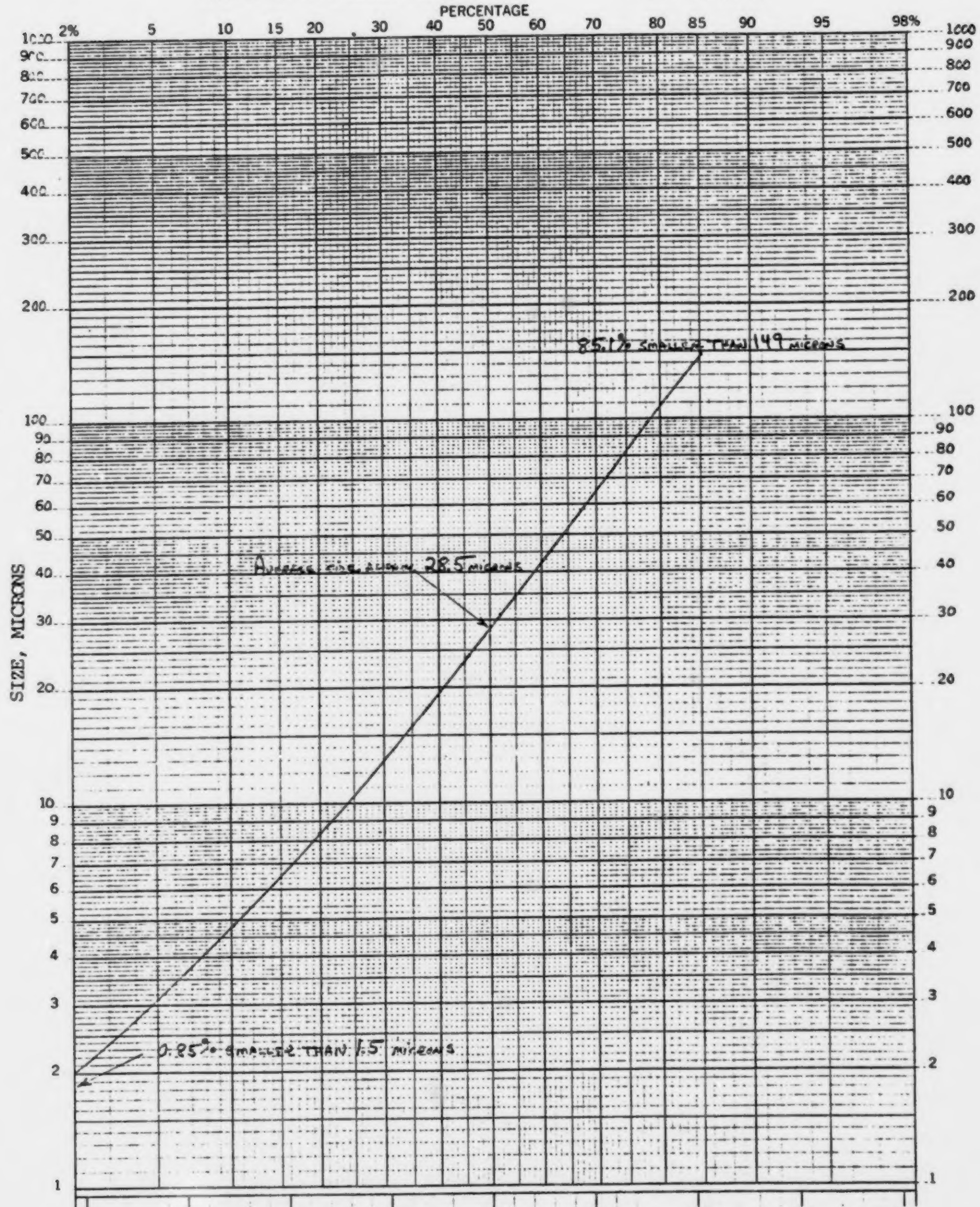
Average size approx 13.5 microns

1.3% smaller than 1.5 microns

CUMULATIVE % LESS THAN STATED SIZE

SAMPLE: Run 3 Inlet 8-14-81 2.07 3/c
COMPANY: ETS
DATE: 9-17-81

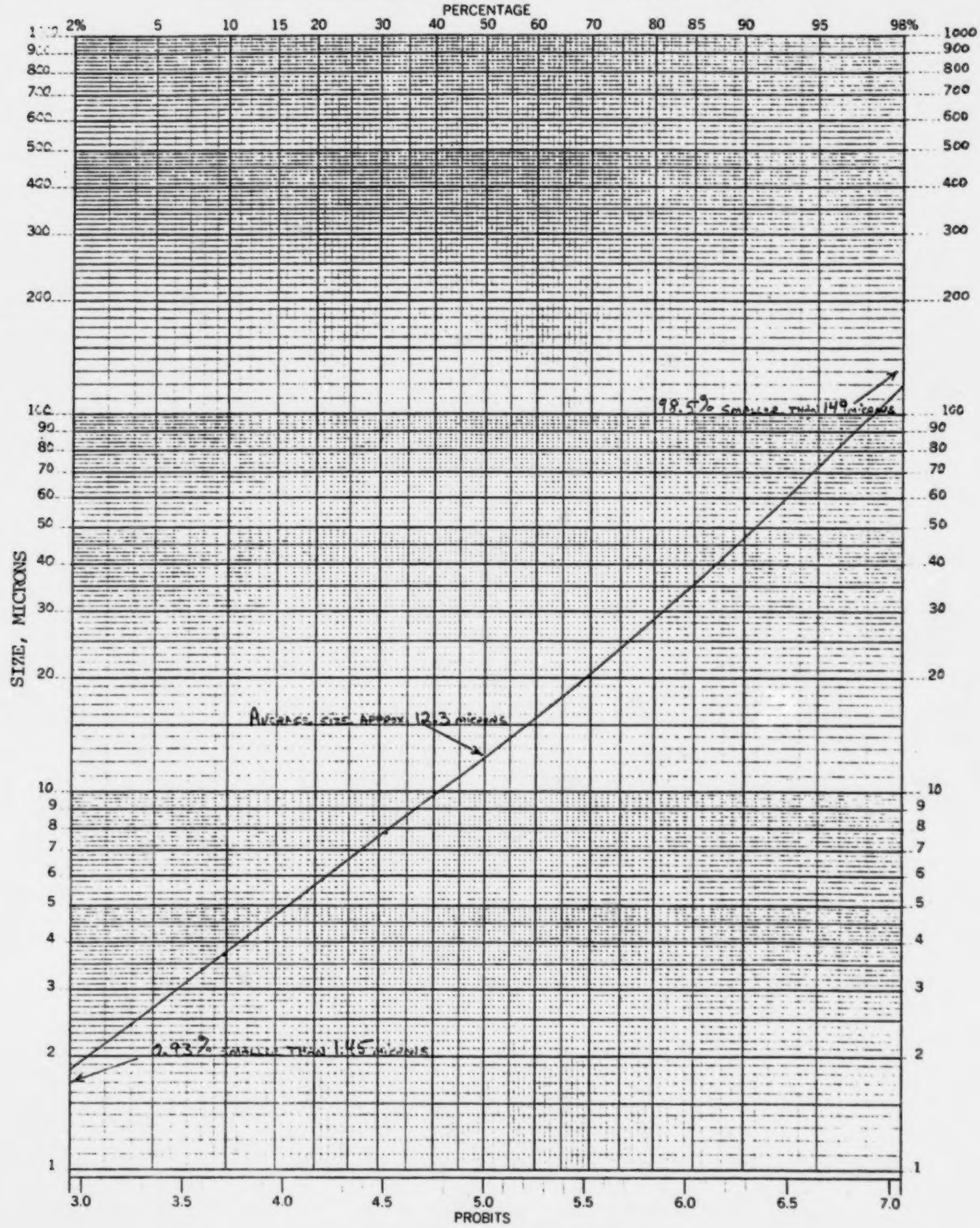
BAHCO ANALYSIS
PARTICLE SIZE DISTRIBUTION



CUMULATIVE % LESS THAN STATED SIZE

BAHCO ANALYSIS
PARTICLE SIZE DISTRIBUTION

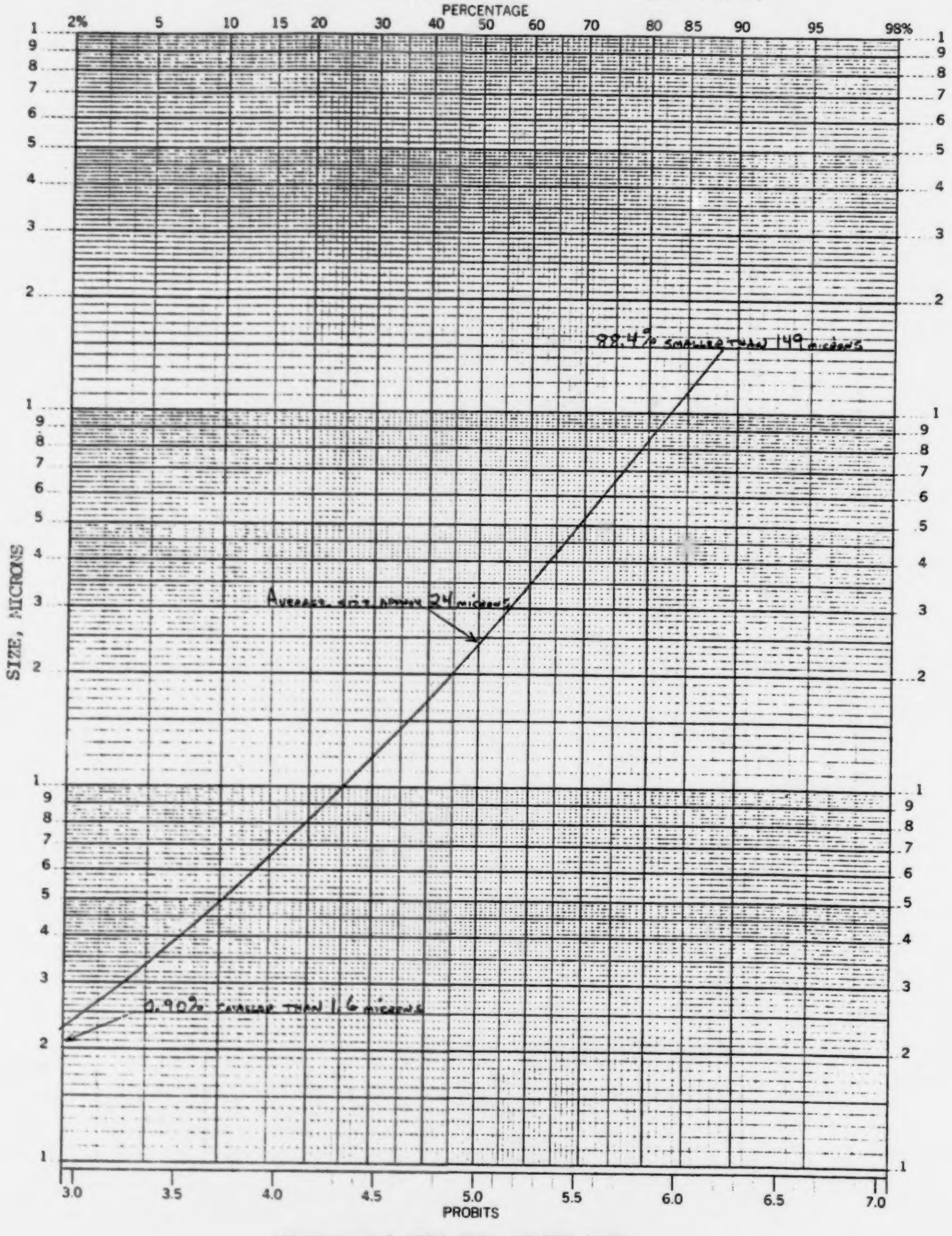
SAMPLE: Run 4 Inlet 8-15-81 2.27g
COMPANY: ETS
DATE: 9-17-81



CUMULATIVE % LESS THAN STATED SIZE

BAHCO ANALYSIS
PARTICLE SIZE DISTRIBUTION

SAMPLE: Run 5 Inlet 8-16-81 1.87%
COMPANY: ETS
DATE: 9-17-81



CUMULATIVE % LESS THAN STATED SIZE

APPENDIX 4

Coal Analysis Results

REPORT OF ANALYSIS

Lab No. 162191
Sample of Coal
PP&L Run 1 - 8/12/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	2.23%	-----%
Ash	15.41%	15.76%
Sulphur	1.90%	1.94%
BTU	12,667	12,956
Carbon	-----	70.43%
Hydrogen	-----	5.37%
Nitrogen	-----	1.43%
Oxygen	-----	5.07%

REPORT OF ANALYSIS

Lab No. 162192
Sample of Coal
PP&L Run 2 - 8/13/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	2.56%	-----%
Ash	17.67	18.13%
Sulphur	1.91%	1.96%
BTU	12,090	12,408
Carbon	-----	67.76%
Hydrogen	-----	4.89%
Nitrogen	-----	1.29%
Oxygen	-----	5.97%

REPORT OF ANALYSIS

Lab No. 162193
Sample of Coal
PP&L Run 3 - 8/14/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	2.34%	-----%
Ash	13.70%	14.03%
Sulphur	2.15%	2.20%
BTU	12,639	12,942
Carbon	-----	71.24%
Hydrogen	-----	4.75%
Nitrogen	-----	1.35%
Oxygen	-----	6.43%

REPORT OF ANALYSIS

Lab No. 162194
Sample of Coal
PP&L Run 4 - 8/15/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	2.10%	-----%
Ash	15.21%	15.54%
Sulphur	2.31%	2.36%
BTU	12,580	12,850
Carbon	-----	71.21%
Hydrogen	-----	4.38%
Nitrogen	-----	1.36%
Oxygen	-----	5.15%

REPORT OF ANALYSIS

Lab No. 162194
Sample of Coal
PP&L Run 5- 8/16/81
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	2.57%	-----%
Ash	15.26%	15.66%
Sulphur	1.71%	1.76%
BTU	12,496	12,827
Carbon	-----	70.01%
Hydrogen	-----	4.59%
Nitrogen	-----	1.40%
Oxygen	-----	6.58%

APPENDIX 5

Bag Analysis Results

ETS, INC.

FABRIC TEST WORKORDER

P. O. No. EPA 68-02-3649 Contract No. 80-138 (P4-80-138)

ETS Specimen Nos. Covered by Workorder 81-195-81-200

Date Workorder Issued September 8, 1981

****

COMPANY

Name EPA - PP&L

Address

Person(s) to Contact Phone No.

Date Received September 2, 1981 Date Shipped

****

TESTS TO BE PERFORMED

	Permeability			Tensile Strength		Mullen Burst	MIT Flex		LOI	Special Requirements
	As Is	Vac@ "	Vac@ "	Warp	Fill		Warp	Fill		
Top	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	Visual Inspection Required Yes(X) No( )
Middle	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	
Bottom	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	Bahco Required Yes( ) No( )
*Other	(X)	( )	( )	( )	( )	( )	( )	( )	( )	
Priority	( )	( )	( )	( )	( )	( )	( )	( )	( )	
Number of Samples										Microscopic Exam Required Yes( ) No( )
Dates Required	September 20									

****

Pertinent Information

*Other Test(s) Required (1)pH of ash on dirty bags. (2)acid flex on clean bags.

Test Requested by J. D. McKenna

Test Authorized by

5111

(04/29/82)

ETS, INC

BAG RECEIVING AND INSPECTION FORM

CUSTOMER COMPANY Pennsylvania Power and Light

CUSTOMER CONTACT Jack Hampson

CUSTOMER BAG I.D. NO.: ____________ CUSTOMER P.O. NO.: ____________

ETS SPECIMEN I.D. NO.: 196-200 ETS CONTRACT NO.: P80-138

DATE: September 10, 1981

INSPECTOR: Jeff Smith

****

INSPECTION:

TYPE OF FABRIC: Glass (10% Tef. B)

AS RECEIVED STATE: ___CLEAN _X_DIRTY _X_FOLDED _X_ENCLOSED IN PLASTIC BAG

DIMENSIONS W.O. TENSION 8 rings

DIMENSIONS W. TENSION(#s) ____________

TEARS AND LOCATION(S) None

CUFF'S AND SEAMS INTEGRITY Good

DUST APPEARANCE Dry

DIRTY BAG WEIGHT ____________

BAG FLEXIBILITY AND MOISTNESS COMMENTS: Dry

BAG SURFACE COMMENTS: ___SMOOTH ___FUZZY _X_UNIFORM ___FOLD OR CAGE LINES

OTHER COMMENTS: Bags relatively clean outside and dirty inside - peraling evident at tops and bottom of bags, but not very heavy in middle.

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ______ Bag Material: Glass (Tef. B)

Contract No: P80-138 Bag Condition: Used

ETS Specimen No: 81-200 Fabric wt., oz/yd^2 10

Customer No: ______ Type of Weave: ______

Customer: PP&L Date: 9/20/81

	BAG SAMPLE				
Permeability, FPM	Top	Middle	Bottom	**Average**	**New Bag**
As Received	2.6	3.6	2.5	2.9	—
After 10 " Vacuum	8.5	12.4	7.4	9.4	
After 30 " Vacuum	17.6	24.4	15.5	19.2	
Other					
Mullen Burst, PSI	342	340	292	325	—
L.O.I., wt. %					—

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	239	109	186	120	225	119	217	116		
MIT FLEX	11988	274	10894	324	4441	285	9108	294		

Dust Sample

pH		3.5
wt.% ash		

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ______ Bag Material: Glass (Tef. B)

Contract No: P80-138 Bag Condition: Used

ETS Specimen No: 81-198 Fabric wt., oz/yd^2 10

Customer No: ______ Type of Weave: ______

Customer: PP&L Date: 9/20/81

	BAG SAMPLE				
	Top	Middle	Bottom	Average	New Bag
Permeability, FPM					
As Received	4.0	5.7	3.5	4.4	—
After 10 " Vacuum	9.8	12.7	9.8	10.8	
After 30 " Vacuum	20.5	22.9	16.0	19.8	
Other					
Mullen Burst, PSI	370	302	297	323	—
L.O.I., wt. %					—

	Top W	Top F	Middle W	Middle F	Bottom W	Bottom F	Average W	Average F	New Bag W	New Bag F
Tensile, lb./in	236	129	183	103	173	110	197	114		
MIT FLEX	3677	547	4475	375	4342	337	4165	420		

Dust Sample

pH ______ 3.3

wt.% ash ______ ______

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ________ Bag Material: Glass (Tef. B)

Contract No: P80-138 Bag Condition: Used

ETS Specimen No: 81-199 Fabric wt., oz/yd^2 10

Customer No: ________ Type of Weave: ________

Customer: PP&L Date: 9/20/81

	BAG SAMPLE				
	Top	Middle	Bottom	Average	New Bag
Permeability, FPM					
As Received	2.8	2.6	2.7	2.7	
After 10 " Vacuum	6.9	6.5	5.4	6.3	
After 30 " Vacuum	19.7	14.3	14.1	16.0	
Other					
Mullen Burst, PSI	370	305	322		
L.O.I., wt. %					

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	234	114	191	105	191	85	205	101		
MIT FLEX	8310	435	6357	150	4268	452	6311	345		

Dust Sample

pH ________

wt.% ash ________

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ______ Bag Material: Glass (Tef. B)

Contract No: P80-138 Bag Condition: Used

ETS Specimen No: 81-197 Fabric wt., oz/yd^2 10

Customer No: ______ Type of Weave: ______

Customer: PP&L Date: 9/20/81

	BAG SAMPLE				
Permeability, FPM	Top	Middle	Bottom	Average	New Bag
As Received	3.4	4.2	4.3	4.0	—
After 10 " Vacuum	6.7	9.6	11.3	9.2	
After ~~30~~ " Vacuum	20.8	20.6	24.6	22	
Other					
Mullen Burst, PSI	380	325	275	327	—
L.O.I., wt. %					—

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	220	115	167	117	182	104	189	112		
MIT FLEX	4566	449	4643	136	5346	412	4852	332		

Dust Sample

pH ______ ______

wt.% ash ______ ______

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ____________ Bag Material: Glass (Tef. B)
Contract No: P80-138 Bag Condition: New
ETS Specimen No: 81-196 Fabric wt., oz/yd^2 10 oz.
Customer No: ____________ Type of Weave: ____________
Customer: PP&L Date: 9/20/81

	BAG SAMPLE				
Permeability, FPM	Top	Middle	Bottom	Average	New Bag
As Received	58.1	58.7	71.2	62.7	___
After 10 " Vacuum				___	
After 30 " Vacuum				___	
Other				___	
Mullen Burst, PSI	550	572	540	554	___
L.O.I., wt. %		9.99	10.42	10.2	___

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	422	209	307	229	333	208	354	215	___	___
MIT FLEX	21057	2949	26813	4930	28674	4743	25515	4207	___	___

Dust Sample

pH ____________ ____________

wt.% ash ____________ ____________

SUMMARY OF FABRIC FILTER TEST DATA

P.O. No.: ______ Bag Material: Glass (Tef. B)
Contract No: P80-138 Bag Condition: New
ETS Specimen No: 81-195 Fabric wt., oz/yd^2 10 oz.
Customer No: ______ Type of Weave: ______
Customer: PP&L Date: 9/20/81

	BAG SAMPLE				
	Top	Middle	Bottom	Average	New Bag
Permeability, FPM					
As Received	33.5	31.9	31.3	32.2	—
After ___" Vacuum					
After ___" Vacuum					
Other					
Mullen Burst, PSI	500	512	457	490	—
L.O.I., wt. %		10.97	11.03	11.0	—

	W	F	W	F	W	F	W	F	W	F
Tensile, lb./in	424	150	290	137	366	150	360	146		
MIT FLEX	65815	7693	71332	8616	88992	3890	72964	6733		
MIT Acid Flex ----							219	6		

Dust Sample

pH ______

wt.% ash ______

APPENDIX 6

Computer Printouts

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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PENNSYLVANIA POWER & LIGHT

PLANT LOCATION  HARRISBURG, PA

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  OUTLET RUN 1

POLLUTANTS      PARTICULATE EMISSIONS

                          ETS, INC.

                          ROANOKE, VIRGINIA

                          8/12/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 8/12/81  RUN 1 OUTLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 1 OUTLET
DATE OF RUN                                     8/12/81
TIME AT BEGINNING OF RUN                         1130
TIME AT END OF RUN                               1530
DN                SAMPLING NOZZLE DIAMETER       .231 IN.
PBAR              BAROMETRIC PRESSURE            29.58 IN.HG.ABS.
TT                NET TIME OF TEST               245 MIN.
VMN               SAMPLE GAS VOLUME              145.646 CU.FT.
TM                AVG.GAS METER TEMPERATURE     %112.0 DEGR.F.
DH                AVG. ORIFICE PRESSURE DROP     1.35 IN.H2O
VMSTD             VOLUME OF DRY GAS SAMPLED     %134.484 DSCF


VLC               H2O FM IMPING. SILICA GEL      172 ML
VWSTD             H2O COLLECTED AT STD.COND.       8.122 STD.CU.FT.
BWS               STACK GAS MOISTURE BY VOL.       5.7 PERCENT
                  CO2 IN DRY STACK GASES          12.2 PERCENT
                  O2 IN DRY STACK GASES            6.0 PERCENT
                  CO IN DRY STACK GASES            0.1 PERCENT
                  N2 IN DRY STACK GASES           81.7 PERCENT
MFDG              MOL FRACTION OF DRY GAS          0.94
EA                EXCESS AIR                     38.54 PERCENT
MS                MOL WGT OF STACK GAS,WET       29.50


SA                STACK AREA                     57600 SQ.IN.
P2                STATIC PRESSURE OF STACK GAS     -1.44 IN.HG.ABS.
PSA               STACK GAS PRESSURE               28.14 IN.HG.ABS.
TS                AVG.STACK TEMPERATURE           294.1 DEGR.F.
VS                STACK GAS VELOC.,STACK COND.    2927 AFPM
QS                STACK GAS VOL.,DRY STD.COND.  %729626 DSCFM
QA                STACK GAS VOLUME,STACK COND.  %1170550 ACFM


I                 ISOKINETIC RATIO              103.1 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  8/12/81  RUN 1 OUTLET PAGE 3


NOZZLE AND THIMBLE               GRAMS            0.0000
                                 GRAINS/ACF       0.0000
                                 GRAINS/SCF       0.0000
                                 LB/HR-CONC       0.00
                                 LB/HR-AREA       0.00
                                 LB/HR-AVG        0.00


PROBE                            GRAMS            0.0989
TOTAL-ABOVE ITEMS                GRAMS            0.0989
                                 GRAINS/ACF       0.0071
                                 GRAINS/SCF       0.0113
                                 LB/HR-CONC      70.82
                                 LB/HR-AREA      73.29
                                 LB/HR-AVG       72.06


FILTER                           GRAMS            0.0198
TOTAL-ABOVE ITEMS                GRAMS            0.1188
                                 GRAINS/ACF       0.0085
                                 GRAINS/SCF       0.0136
                                 LB/HR-CONC      85.03
                                 LB/HR-AREA      88.00
                                 LB/HR-AVG       86.51


TOTAL-INCL.IMPINGER CATCH      GRAMS            0.1188
                                 GRAINS/ACF       0.0085
                                 GRAINS/SCF       0.0136
                                 LB/HR-CONC      85.03
                                 LB/HR-AREA      88.00
                                 LB/HR-AVG       86.51


E,EMISSION RATE (F FACTOR CALCULATION)   .0272205 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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SOURCE ISOKINETIC SAMPLING ANALYSIS


PROGRAM METH5


CLIENT NAME      PENNSYLVANIA POWER & LIGHT

PLANT LOCATION   HARRISBURG, PA

PROCESS          COAL-FIRED BOILER

CONTROL EQUIPMT  BAGHOUSE

SAMPLING POINT   OUTLET RUN 2

POLLUTANTS       PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         08/13/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/13/81  RUN 2 OUTLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                         RUN 2 OUTLET
DATE OF RUN                                        08/13/81
TIME AT BEGINNING OF RUN                            1000
TIME AT END OF RUN                                  1400
DN              SAMPLING NOZZLE DIAMETER            .231 IN.
PBAR            BAROMETRIC PRESSURE                 29.65 IN.HG.ABS.
TT              NET TIME OF TEST                    245 MIN.
VMN             SAMPLE GAS VOLUME                   136.105 CU.FT.
TM              AVG.GAS METER TEMPERATURE          %103.9 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP          1.23 IN.H20
VMSTD           VOLUME OF DRY GAS SAMPLED          %127.740 DSCF


VLC             H20 FM IMPING. SILICA GEL           229 ML
VWSTD           H20 COLLECTED AT STD.COND.          10.814 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.           7.8 PERCENT
                CO2 IN DRY STACK GASES              12.9 PERCENT
                O2 IN DRY STACK GASES                5.3 PERCENT
                CO IN DRY STACK GASES                0.2 PERCENT
                N2 IN DRY STACK GASES               81.6 PERCENT
MFDG            MOL FRACTION OF DRY GAS              0.92
EA              EXCESS AIR                          32.63 PERCENT
MS              MOL WGT OF STACK GAS,WET            29.32


SA              STACK AREA                          57600 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS          -1.45 IN.HG.ABS.
PSA             STACK GAS PRESSURE                    28.20 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE                289.4 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.        2774 AFPM
QS              STACK GAS VOL.,DRY STD.COND.       %681814 DSCFM
QA              STACK GAS VOLUME,STACK COND.       %1109390 ACFM


I               ISOKINETIC RATIO                    104.8 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/13/81  RUN 2 OUTLET PAGE 3


NOZZLE AND THIMBLE                GRAMS              0.0000
                                  GRAINS/ACF         0.0000
                                  GRAINS/SCF         0.0000
                                  LB/HR-CONC         0.00
                                  LB/HR-AREA         0.00
                                  LB/HR-AVG          0.00


PROBE                             GRAMS              0.0580
TOTAL-ABOVE ITEMS                 GRAMS              0.0580
                                  GRAINS/ACF         0.0043
                                  GRAINS/SCF         0.0070
                                  LB/HR-CONC        40.82
                                  LB/HR-AREA        42.94
                                  LB/HR-AVG         41.88


FILTER                            GRAMS              0.0179
TOTAL-ABOVE ITEMS                 GRAMS              0.0759
                                  GRAINS/ACF         0.0056
                                  GRAINS/SCF         0.0091
                                  LB/HR-CONC        53.45
                                  LB/HR-AREA        56.22
                                  LB/HR-AVG         54.83


TOTAL-INCL.IMPINGER CATCH       GRAMS              0.0759
                                  GRAINS/ACF         0.0056
                                  GRAINS/SCF         0.0091
                                  LB/HR-CONC        53.45
                                  LB/HR-AREA        56.22
                                  LB/HR-AVG         54.83

E,EMISSION RATE (F FACTOR CALCULATION)   .0176343 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PENNSYLVANIA POWER & LIGHT
PLANT LOCATION  HARRISBURG, PA
PROCESS         COAL-FIRED BOILER
CONTROL EQUIPMT BAGHOUSE
SAMPLING POINT  OUTLET RUN 3
POLLUTANTS      PARTICULATE EMISSIONS
                         ETS, INC.
                         ROANOKE, VIRGINIA
                         08/14/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/14/81  RUN 3 OUTLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                       RUN 3 OUTLET
DATE OF RUN                                      08/14/81
TIME AT BEGINNING OF RUN                           935
TIME AT END OF RUN                                 1330
DN              SAMPLING NOZZLE DIAMETER           .231 IN.
PBAR            BAROMETRIC PRESSURE                29.7 IN.HG.ABS.
TT              NET TIME OF TEST                   245 MIN.
VMN             SAMPLE GAS VOLUME                  156.74 CU.FT.
TM              AVG.GAS METER TEMPERATURE        %108.9 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP         1.17 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED        %146.039 DSCF


VLC             H2O FM IMPING. SILICA GEL          254 ML
VWSTD           H2O COLLECTED AT STD.COND.         11.994 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.          7.6 PERCENT
                CO2 IN DRY STACK GASES             12.9 PERCENT
                O2 IN DRY STACK GASES               5.3 PERCENT
                CO IN DRY STACK GASES               0.1 PERCENT
                N2 IN DRY STACK GASES              81.7 PERCENT
MFDG            MOL FRACTION OF DRY GAS             0.92
EA              EXCESS AIR                         32.58 PERCENT
MS              MOL WGT OF STACK GAS,WET           29.34


SA              STACK AREA                         57600 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS         -1.43 IN.HG.ABS.
PSA             STACK GAS PRESSURE                   28.27 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE               280.2 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.       3128 AFPM
QS              STACK GAS VOL.,DRY STD.COND.     %781912 DSCFM
QA              STACK GAS VOLUME,STACK COND.     %1250950 ACFM


I               ISOKINETIC RATIO                 104.5 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/14/81  RUN 3 OUTLET PAGE 3


NOZZLE AND THIMBLE               GRAMS              0.0755
                                 GRAINS/ACF         0.0050
                                 GRAINS/SCF         0.0080
                                 LB/HR-CONC        53.34
                                 LB/HR-AREA        55.93
                                 LB/HR-AVG         54.63


PROBE                            GRAMS              0.3069
TOTAL-ABOVE ITEMS                GRAMS              0.3824
                                 GRAINS/ACF         0.0252
                                 GRAINS/SCF         0.0403
                                 LB/HR-CONC        %270.19
                                 LB/HR-AREA        %283.34
                                 LB/HR-AVG         %276.77


FILTER                           GRAMS              0.0033
TOTAL-ABOVE ITEMS                GRAMS              0.3857
                                 GRAINS/ACF         0.0254
                                 GRAINS/SCF         0.0407
                                 LB/HR-CONC        %272.51
                                 LB/HR-AREA        %285.77
                                 LB/HR-AVG         %279.14


TOTAL-INCL.IMPINGER CATCH      GRAMS              0.3857
                                 GRAINS/ACF         0.0254
                                 GRAINS/SCF         0.0407
                                 LB/HR-CONC        %272.51
                                 LB/HR-AREA        %285.77
                                 LB/HR-AVG         %279.14


E,EMISSION RATE (F FACTOR CALCULATION)   .0782794 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME       PENNSYLVANIA POWER & LIGHT
PLANT LOCATION    HARRISBURG, PA
PROCESS           COAL-FIRED BOILER
CONTROL EQUIPMT   BAGHOUSE
SAMPLING POINT    OUTLET RUN 4
POLLUTANTS        PARTICULATE EMISSIONS
                            ETS, INC.
                            ROANOKE, VIRGINIA
                            08/15/81
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                1.18            %154.914        %100.8          3158.5
                (AVG)           (NET)           (AVG)           (AVG)
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/15/81  RUN 4 OUTLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 4 OUTLET
DATE OF RUN                                     08/15/81
TIME AT BEGINNING OF RUN                         915
TIME AT END OF RUN                               1315
DN              SAMPLING NOZZLE DIAMETER         .23 IN.
PBAR            BAROMETRIC PRESSURE              29.54 IN.HG.ABS.
TT              NET TIME OF TEST                 245 MIN.
VMN             SAMPLE GAS VOLUME                154.914 CU.FT.
TM              AVG.GAS METER TEMPERATURE       %100.8 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       1.18 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       %145.646 DSCF

VLC             H2O FM IMPING. SILICA GEL        253 ML
VWSTD           H2O COLLECTED AT STD.COND.       11.947 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.        7.6 PERCENT
                CO2 IN DRY STACK GASES           13.1 PERCENT
                O2 IN DRY STACK GASES             5.3 PERCENT
                CO IN DRY STACK GASES             0.1 PERCENT
                N2 IN DRY STACK GASES            81.5 PERCENT
MFDG            MOL FRACTION OF DRY GAS           0.92
EA              EXCESS AIR                       32.68 PERCENT
MS              MOL WGT OF STACK GAS,WET         29.37

SA              STACK AREA                       57600 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -1.43 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 28.11 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             281.9 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     3159 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %783440 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1263340 ACFM

I               ISOKINETIC RATIO                104.9 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/15/81  RUN 4 OUTLET PAGE 3


NOZZLE AND THIMBLE                GRAMS             0.0914
                                  GRAINS/ACF        0.0060
                                  GRAINS/SCF        0.0097
                                  LB/HR-CONC       64.89
                                  LB/HR-AREA       68.33
                                  LB/HR-AVG        66.61

PROBE                             GRAMS             0.0854
TOTAL-ABOVE ITEMS                 GRAMS             0.1768
                                  GRAINS/ACF        0.0116
                                  GRAINS/SCF        0.0187
                                  LB/HR-CONC       %125.54
                                  LB/HR-AREA       %132.18
                                  LB/HR-AVG        %128.86

FILTER                            GRAMS             0.0035
TOTAL-ABOVE ITEMS                 GRAMS             0.1803
                                  GRAINS/ACF        0.0118
                                  GRAINS/SCF        0.0191
                                  LB/HR-CONC       %128.03
                                  LB/HR-AREA       %134.80
                                  LB/HR-AVG        %131.41

TOTAL-INCL.IMPINGER CATCH       GRAMS             0.1803
                                  GRAINS/ACF        0.0118
                                  GRAINS/SCF        0.0191
                                  LB/HR-CONC       %128.03
                                  LB/HR-AREA       %134.80
                                  LB/HR-AVG        %131.41

E,EMISSION RATE (F FACTOR CALCULATION)   .0367801 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PENNSYLVANIA POWER & LIGHT

PLANT LOCATION  HARRISBURG, PA

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  OUTLET RUN 5

POLLUTANTS      PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         08/16/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/16/81  RUN 5 OUTLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 5 OUTLET
DATE OF RUN                                     08/16/81
TIME AT BEGINNING OF RUN                         915
TIME AT END OF RUN                               1315
DN              SAMPLING NOZZLE DIAMETER         .231 IN.
PBAR            BAROMETRIC PRESSURE              29.34 IN.HG.ABS.
TT              NET TIME OF TEST                 245 MIN.
VMN             SAMPLE GAS VOLUME                160.635 CU.FT.
TM              AVG.GAS METER TEMPERATURE       %107.0 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       1.24 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       %148.379 DSCF


VLC             H2O FM IMPING. SILICA GEL        228 ML
VWSTD           H2O COLLECTED AT STD.COND.       10.766 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.         6.8 PERCENT
                CO2 IN DRY STACK GASES           13.1 PERCENT
                O2 IN DRY STACK GASES             5.2 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.7 PERCENT
MFDG            MOL FRACTION OF DRY GAS           0.93
EA              EXCESS AIR                       31.77 PERCENT
MS              MOL WGT OF STACK GAS,WET         29.47


SA              STACK AREA                       57600 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -1.43 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 27.91 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             315.6 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     3325 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %790297 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1330110 ACFM


I               ISOKINETIC RATIO                105.0 PERCENT
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```
ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/16/81  RUN 5 OUTLET PAGE 3



NOZZLE AND THIMBLE                GRAMS             0.0765
                                  GRAINS/ACF        0.0047
                                  GRAINS/SCF        0.0079
                                  LB/HR-CONC       53.78
                                  LB/HR-AREA       56.69
                                  LB/HR-AVG        55.23


PROBE                             GRAMS             0.0495
TOTAL-ABOVE ITEMS                 GRAMS             0.1260
                                  GRAINS/ACF        0.0078
                                  GRAINS/SCF        0.0131
                                  LB/HR-CONC       88.60
                                  LB/HR-AREA       93.40
                                  LB/HR-AVG        91.00


FILTER                            GRAMS             0.0030
TOTAL-ABOVE ITEMS                 GRAMS             0.1290
                                  GRAINS/ACF        0.0080
                                  GRAINS/SCF        0.0134
                                  LB/HR-CONC       90.71
                                  LB/HR-AREA       95.62
                                  LB/HR-AVG        93.16


TOTAL-INCL.IMPINGER CATCH       GRAMS             0.1290
                                  GRAINS/ACF        0.0080
                                  GRAINS/SCF        0.0134
                                  LB/HR-CONC       90.71
                                  LB/HR-AREA       95.62
                                  LB/HR-AVG        93.16


E,EMISSION RATE (F FACTOR CALCULATION)   .0256841 LBS/MILLION BTU, FUEL TYPE BITUMINUS
```

```
SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PENNSYLVANIA POWER & LIGHT
PLANT LOCATION  HARRISBURG, PA
PROCESS         COAL-FIRED BOILER
CONTROL EQUIPMT BAGHOUSE
SAMPLING POINT  INLET RUN 1
POLLUTANTS      PARTICULATE EMISSIONS
                         ETS, INC.
                         ROANOKE, VIRGINIA
                          08/12/81
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                DH              VMN             TM
                0.44            91.747          %102.5          3411.0
                (AVG)           (NET)           (AVG)           (AVG)
```

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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/12/81  RUN 1 INLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                   RUN 1 INLET
DATE OF RUN                                  08/12/81
TIME AT BEGINNING OF RUN                      1130
TIME AT END OF RUN                            1530
DN              SAMPLING NOZZLE DIAMETER      .175 IN.
PBAR            BAROMETRIC PRESSURE           29.6 IN.HG.ABS.
TT              NET TIME OF TEST              240 MIN.
VMN             SAMPLE GAS VOLUME             91.747 CU.FT.
TM              AVG.GAS METER TEMPERATURE    %102.5 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP    0.44 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED    84.747 DSCF


VLC             H2O FM IMPING. SILICA GEL     222 ML
VWSTD           H2O COLLECTED AT STD.COND.    10.483 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.    11.0 PERCENT
                CO2 IN DRY STACK GASES        13.1 PERCENT
                O2 IN DRY STACK GASES          5.4 PERCENT
                CO IN DRY STACK GASES          0.0 PERCENT
                N2 IN DRY STACK GASES         81.5 PERCENT
MFDG            MOL FRACTION OF DRY GAS        0.89
EA              EXCESS AIR                     33.51 PERCENT
MS              MOL WGT OF STACK GAS,WET      28.96


SA              STACK AREA                    41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS     -0.71 IN.HG.ABS.
PSA             STACK GAS PRESSURE               28.89 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE          285.6 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.   3411 AFPM
QS              STACK GAS VOL.,DRY STD.COND. %600058 DSCFM
QA              STACK GAS VOLUME,STACK COND. %982312 ACFM


I               ISOKINETIC RATIO             101.2 PERCENT
```

```
ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/12/81  RUN 1 INLET PAGE 3


NOZZLE AND THIMBLE              GRAMS           54.7120
                                GRAINS/ACF       6.0723
                                GRAINS/SCF       9.9421
                                LB/HR-CONC      %51127.20
                                LB/HR-AREA      %51920.90
                                LB/HR-AVG       %51524.10

PROBE                           GRAMS            0.8164
TOTAL-ABOVE ITEMS               GRAMS           55.5284
                                GRAINS/ACF       6.1629
                                GRAINS/SCF      10.0905
                                LB/HR-CONC      %51890.20
                                LB/HR-AREA      %52695.70
                                LB/HR-AVG       %52292.90

FILTER                          GRAMS            0.0001
TOTAL-ABOVE ITEMS               GRAMS           55.5285
                                GRAINS/ACF       6.1629
                                GRAINS/SCF      10.0905
                                LB/HR-CONC      %51890.20
                                LB/HR-AREA      %52695.80
                                LB/HR-AVG       %52293.00

TOTAL-INCL.IMPINGER CATCH     GRAMS           55.5285
                                GRAINS/ACF       6.1629
                                GRAINS/SCF      10.0905
                                LB/HR-CONC      %51890.20
                                LB/HR-AREA      %52695.80
                                LB/HR-AVG       %52293.00

E,EMISSION RATE (F FACTOR CALCULATION)   19.232 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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```
SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PENNSYLVANIA POWER & LIGHT
PLANT LOCATION  HARRISBURG, PA
PROCESS         COAL-FIRED BOILER
CONTROL EQUIPMT BAGHOUSE
SAMPLING POINT  INLET RUN 2
POLLUTANTS      PARTICULATE EMISSIONS
                          ETS, INC.
                          ROANOKE, VIRGINIA
                          08/13/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/13/81  RUN 2 INLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 2 INLET
DATE OF RUN                                     08/13/81
TIME AT BEGINNING OF RUN                         1000
TIME AT END OF RUN                               1400
DN              SAMPLING NOZZLE DIAMETER         .178 IN.
PBAR            BAROMETRIC PRESSURE              29.65 IN.HG.ABS.
TT              NET TIME OF TEST                 240 MIN.
VMN             SAMPLE GAS VOLUME                108.12 CU.FT.
TM              AVG.GAS METER TEMPERATURE       %101.1 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       0.63 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       %100.340 DSCF


VLC             H2O FM IMPING. SILICA GEL        188 ML
VWSTD           H2O COLLECTED AT STD.COND.        8.878 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.        8.1 PERCENT
                CO2 IN DRY STACK GASES           12.7 PERCENT
                O2 IN DRY STACK GASES             5.4 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.9 PERCENT
MFDG            MOL FRACTION OF DRY GAS           0.92
EA              EXCESS AIR                       33.29 PERCENT
MS              MOL WGT OF STACK GAS,WET         29.25


SA              STACK AREA                       41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -0.71 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 28.94 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE              289.5 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     3947 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %714414 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1136780 ACFM


I               ISOKINETIC RATIO                 97.2 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/13/81  RUN 2 INLET PAGE 3


NOZZLE AND THIMBLE               GRAMS           29.7493
                                 GRAINS/ACF       2.8690
                                 GRAINS/SCF       4.5659
                                 LB/HR-CONC      %27954.60
                                 LB/HR-AREA      %27288.10
                                 LB/HR-AVG       %27621.30


PROBE                            GRAMS            0.9557
TOTAL-ABOVE ITEMS                GRAMS           30.7051
                                 GRAINS/ACF       2.9611
                                 GRAINS/SCF       4.7125
                                 LB/HR-CONC      %28852.70
                                 LB/HR-AREA      %28164.80
                                 LB/HR-AVG       %28508.70


FILTER                           GRAMS            0.0055
TOTAL-ABOVE ITEMS                GRAMS           30.7106
                                 GRAINS/ACF       2.9616
                                 GRAINS/SCF       4.7134
                                 LB/HR-CONC      %28857.80
                                 LB/HR-AREA      %28169.80
                                 LB/HR-AVG       %28513.80


TOTAL-INCL.IMPINGER CATCH      GRAMS           30.7106
                                 GRAINS/ACF       2.9616
                                 GRAINS/SCF       4.7134
                                 LB/HR-CONC      %28857.80
                                 LB/HR-AREA      %28169.80
                                 LB/HR-AVG       %28513.80


E,EMISSION RATE (F FACTOR CALCULATION)   8.80806 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME      PENNSYLVANIA POWER & LIGHT
PLANT LOCATION   HARRISBURG, PA
PROCESS          COAL-FIRED BOILER
CONTROL EQUIPMT  BAGHOUSE
SAMPLING POINT   INLET RUN 3
POLLUTANTS       PARTICULATE EMISSIONS
                          ETS, INC.
                          ROANOKE, VIRGINIA
                          08/14/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/14/81  RUN 3 INLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                        RUN 3 INLET
DATE OF RUN                                       08/14/81
TIME AT BEGINNING OF RUN                           930
TIME AT END OF RUN                                 1330
DN              SAMPLING NOZZLE DIAMETER           .178 IN.
PBAR            BAROMETRIC PRESSURE                29.7 IN.HG.ABS.
TT              NET TIME OF TEST                   240 MIN.
VMN             SAMPLE GAS VOLUME                  98.814 CU.FT.
TM              AVG.GAS METER TEMPERATURE         %104.0 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP         0.59 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED         91.370 DSCF


VLC             H20 FM IMPING. SILICA GEL          194 ML
VWSTD           H20 COLLECTED AT STD.COND.           9.161 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.           9.1 PERCENT
                CO2 IN DRY STACK GASES             12.1 PERCENT
                O2 IN DRY STACK GASES               5.7 PERCENT
                CO IN DRY STACK GASES               0.0 PERCENT
                N2 IN DRY STACK GASES              82.2 PERCENT
MFDG            MOL FRACTION OF DRY GAS             0.91
EA              EXCESS AIR                         35.62 PERCENT
MS              MOL WGT OF STACK GAS,WET           29.06


SA              STACK AREA                         41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS         -0.71 IN.HG.ABS.
PSA             STACK GAS PRESSURE                    28.99 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE               290.1 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.       3848 AFPM
QS              STACK GAS VOL.,DRY STD.COND.      %689491 DSCFM
QA              STACK GAS VOLUME,STACK COND.      %1108070 ACFM


I               ISOKINETIC RATIO                   91.7 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/14/81  RUN 3 INLET PAGE 3


NOZZLE AND THIMBLE               GRAMS          35.3945
                                 GRAINS/ACF      3.7115
                                 GRAINS/SCF      5.9656
                                 LB/HR-CONC     %35250.30
                                 LB/HR-AREA     %32466.20
                                 LB/HR-AVG      %33858.30


PROBE                            GRAMS           1.5321
TOTAL-ABOVE ITEMS                GRAMS          36.9266
                                 GRAINS/ACF      3.8721
                                 GRAINS/SCF      6.2238
                                 LB/HR-CONC     %36776.20
                                 LB/HR-AREA     %33871.50
                                 LB/HR-AVG      %35323.90


FILTER                           GRAMS           0.0614
TOTAL-ABOVE ITEMS                GRAMS          36.9879
                                 GRAINS/ACF      3.8785
                                 GRAINS/SCF      6.2342
                                 LB/HR-CONC     %36837.30
                                 LB/HR-AREA     %33927.80
                                 LB/HR-AVG      %35382.60


TOTAL-INCL.IMPINGER CATCH      GRAMS          36.9879
                                 GRAINS/ACF      3.8785
                                 GRAINS/SCF      6.2342
                                 LB/HR-CONC     %36837.30
                                 LB/HR-AREA     %33927.80
                                 LB/HR-AVG      %35382.60

E,EMISSION RATE (F FACTOR CALCULATION)   11.5485 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PENNSYLVANIA POWER & LIGHT

PLANT LOCATION  HARRISBURG, PA

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  INLET RUN 4

POLLUTANTS      PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         08/15/81
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/15/81  RUN 4 INLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 4 INLET
DATE OF RUN                                     08/15/81
TIME AT BEGINNING OF RUN                         915
TIME AT END OF RUN                               1315
DN               SAMPLING NOZZLE DIAMETER        .178 IN.
PBAR             BAROMETRIC PRESSURE             29.54 IN.HG.ABS.
TT               NET TIME OF TEST                245 MIN.
VMN              SAMPLE GAS VOLUME               103.097 CU.FT.
TM               AVG.GAS METER TEMPERATURE      %102.7 DEGR.F.
DH               AVG. ORIFICE PRESSURE DROP     0.62 IN.H2O
VMSTD            VOLUME OF DRY GAS SAMPLED      95.044 DSCF


VLC              H2O FM IMPING. SILICA GEL       178 ML
VWSTD            H2O COLLECTED AT STD.COND.        8.405 STD.CU.FT.
BWS              STACK GAS MOISTURE BY VOL.        8.1 PERCENT
                 CO2 IN DRY STACK GASES          13.0 PERCENT
                 O2 IN DRY STACK GASES             5.3 PERCENT
                 CO  IN DRY STACK GASES            0.0 PERCENT
                 N2 IN DRY STACK GASES           81.7 PERCENT
MFDG             MOL FRACTION OF DRY GAS           0.92
EA               EXCESS AIR                       32.58 PERCENT
MS               MOL WGT OF STACK GAS,WET         29.29


SA               STACK AREA                      41472 SQ.IN.
P2               STATIC PRESSURE OF STACK GAS       -0.71 IN.HG.ABS.
PSA              STACK GAS PRESSURE                 28.83 IN.HG.ABS.
TS               AVG.STACK TEMPERATURE             292.5 DEGR.F.
VS               STACK GAS VELOC.,STACK COND.     3951 AFPM
QS               STACK GAS VOL.,DRY STD.COND.   %709517 DSCFM
QA               STACK GAS VOLUME,STACK COND.   %1137890 ACFM


I                ISOKINETIC RATIO                 90.8 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/15/81  RUN 4 INLET PAGE 3


NOZZLE AND THIMBLE                GRAMS           42.6562
                                  GRAINS/ACF       4.3089
                                  GRAINS/SCF       6.9116
                                  LB/HR-CONC      %42026.20
                                  LB/HR-AREA      %38328.60
                                  LB/HR-AVG       %40177.40


PROBE                             GRAMS            0.1490
TOTAL-ABOVE ITEMS                 GRAMS           42.8051
                                  GRAINS/ACF       4.3240
                                  GRAINS/SCF       6.9357
                                  LB/HR-CONC      %42172.90
                                  LB/HR-AREA      %38462.40
                                  LB/HR-AVG       %40317.70


FILTER                            GRAMS            0.0025
TOTAL-ABOVE ITEMS                 GRAMS           42.8076
                                  GRAINS/ACF       4.3242
                                  GRAINS/SCF       6.9361
                                  LB/HR-CONC      %42175.40
                                  LB/HR-AREA      %38464.70
                                  LB/HR-AVG       %40320.00


TOTAL-INCL.IMPINGER CATCH       GRAMS           42.8076
                                  GRAINS/ACF       4.3242
                                  GRAINS/SCF       6.9361
                                  LB/HR-CONC      %42175.40
                                  LB/HR-AREA      %38464.70
                                  LB/HR-AVG       %40320.00


E,EMISSION RATE (F FACTOR CALCULATION)   12.4606 LBS/MILLION BTU, FUEL TYPE BITUMINUS
```

SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME	PENNSYLVANIA POWER & LIGHT
PLANT LOCATION	HARRISBURG, PA
PROCESS	COAL FIRED-BOILER
CONTROL EQUIPMT	BAGHOUSE
SAMPLING POINT	INLET RUN 5
POLLUTANTS	PARTICULATE EMISSIONS

ETS, INC.
ROANOKE, VIRGINIA
08/16/81

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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 08/16/81  RUN 5 INLET PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 5 INLET
DATE OF RUN                                     08/16/81
TIME AT BEGINNING OF RUN                         905
TIME AT END OF RUN                               1305
DN              SAMPLING NOZZLE DIAMETER         .178 IN.
PBAR            BAROMETRIC PRESSURE              29.34 IN.HG.ABS.
TT              NET TIME OF TEST                 245 MIN.
VMN             SAMPLE GAS VOLUME                98.1311 CU.FT.
TM              AVG.GAS METER TEMPERATURE       97.6 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       0.59 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       90.662 DSCF


VLC             H2O FM IMPING. SILICA GEL        159 ML
VWSTD           H2O COLLECTED AT STD.COND.        7.508 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.        7.6 PERCENT
                CO2 IN DRY STACK GASES           13.1 PERCENT
                O2 IN DRY STACK GASES             5.2 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.7 PERCENT
MFDG            MOL FRACTION OF DRY GAS          0.92
EA              EXCESS AIR                       31.77 PERCENT
MS              MOL WGT OF STACK GAS,WET         29.36


SA              STACK AREA                       41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -0.71 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 28.63 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             299.8 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     3882 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %689207 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1117970 ACFM


I               ISOKINETIC RATIO                 89.2 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  08/16/81  RUN 5 INLET PAGE 3


NOZZLE AND THIMBLE                GRAMS            44.2677
                                  GRAINS/ACF        4.6348
                                  GRAINS/SCF        7.5194
                                  LB/HR-CONC       %44413.30
                                  LB/HR-AREA       %39776.70
                                  LB/HR-AVG        %42095.00

PROBE                             GRAMS             0.2057
TOTAL-ABOVE ITEMS                 GRAMS            44.4734
                                  GRAINS/ACF        4.6563
                                  GRAINS/SCF        7.5543
                                  LB/HR-CONC       %44619.70
                                  LB/HR-AREA       %39961.50
                                  LB/HR-AVG        %42290.60

FILTER                            GRAMS             0.0041
TOTAL-ABOVE ITEMS                 GRAMS            44.4776
                                  GRAINS/ACF        4.6568
                                  GRAINS/SCF        7.5550
                                  LB/HR-CONC       %44623.80
                                  LB/HR-AREA       %39965.20
                                  LB/HR-AVG        %42294.50

TOTAL-INCL.IMPINGER CATCH       GRAMS            44.4776
                                  GRAINS/ACF        4.6568
                                  GRAINS/SCF        7.5550
                                  LB/HR-CONC       %44623.80
                                  LB/HR-AREA       %39965.20
                                  LB/HR-AVG        %42294.50


E,EMISSION RATE (F FACTOR CALCULATION)   13.3703 LBS/MILLION BTU, FUEL TYPE BITUMINUS
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APPENDIX 7

Quality Assurance Report

RTI

RESEARCH TRIANGLE INSTITUTE

QUANTITATIVE FIELD AUDIT REPORT

Brunner Island Station
Pennsylvania Power and Light Company
Pennsylvania

by

D. S. Ensor and A. D. Shendrikar

Research Triangle Institute
P. O. Box 12194
Research Triangle Park, North Carolina 27709

October 1981

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

SECTION 1

INTRODUCTION

The field testing at the Brunner Island Station, owned and operated by the Pennsylvania Power and Light Company, required sampling using EPA Method 5 and impactors. The objective of the EPA Method 5 sampling was to evaluate the ability of the baghouses to meet the new source performance standard for particulate matter. Three simultaneous inlet and outlet Method 5 tests were carried out during the week of August 10-14, 1981. The objective of two inlet and outlet impactor tests (carried out during the same week) was to measure the size segregated particulate matter emissions from the fabric filter baghouses. Orsat samplings on a semi-continuous basis were performed to obtain flue gas compositional data.

It was the responsibility of Dr. D. S. Ensor and Dr. A. D. Shendrikar, both of the Research Triangle Institute (RTI), to provide quality assurance (QA) audits on EPA Method 5 and Orsat tests. Dr. Ensor acted as QA officer on August 12, 1981, and Dr. Shendrikar performed this task on the remaining two days. The quality assurance objectives of the project were:

1. To assure reliability of data obtained via EPA Method 5 and Orsat tests.
2. To provide adequate documentation which would support data validity.

SECTION 2

APPROACH

The quality assurance efforts were centered around the following parameters during the field testing at the Brunner Island Station:

1. Presampling procedures.
2. Calibration procedures and frequency.
3. Sampling procedures.
4. Sample recovery and custody.
5. Analytical procedures.
6. Data reduction, validation, and reporting.
7. Preventive maintenance

The attached field audit reports (see the Appendix) for three sampling days give all the details of the quality assurance efforts expended. Most of the above-mentioned parameters were included in such an evaluation.

SECTION 3

RESULTS

From a quality assurance point of view, the testing using EPA Method 5 and Orsat, went satisfactorily. Care was exercised when and where needed. All sampling procedures were adequate and well planned. The sampling crew was highly mechanically oriented and methodic. In spite of the length of the probe (20 ft), no major problems were encountered during sampling (Method 5) nor during port changes. The exception was on the first day of inlet sampling when a minor accident resulted in a bent probe before the start of the test. The probe could not be replaced during subsequent inlet samplings. The bend in the probe may have had some effects on the total particulate matter collected at the inlet, but it was only the outlet testing that was being performed for compliance purposes.

The major problem in the test was that spent silica gel was used in the impinger trains, and this may have had some effect on the determination of moisture content of the flue gas.

The sampling crew came to the site adequately prepared with ample spare equipment and accessories. The supply of silica gel apparently was misplaced. Sample recovery methods were satisfactory, and probe lengths did not affect this task. All samples were recovered in properly labeled containers and stored safely.

The quantitative checks of the Orsat and Method 5 trains in Tables 1 and 2 were inconclusive. The Orsat analysis was very consistent. However, the audit cylinder was returned from the field empty, and the analysis could not be validated in the RTI laboratories. For this reason, the audit of O_2 tests will be repeated on future sampling trips. The Method 5 train audit was also inconclusive. The pump vacuum was below the recommended 17 in. Hg with the audit orifice. It is believed that this explains the difference between the

Table 1. Orsat Measurements of Audit Cylinder

Date	Reported O_2 (%)
8/13/81	5.0
	4.9
8/14/81	5.0
	4.7
	4.8
	5.0
	5.0
	4.6
	4.2
	3.9
	4.6
	4.8
	4.8
	4.2
	4.0
Mean ($\bar{x}$)	4.63
Standard deviation (σ)	0.379
Standard error ($\sigma/\bar{x}$)	8.18

The vendor-determined O_2 concentration of the cylinder was 6.1%. The cylinder was returned from the field empty, and the analysis could not be validated in RTI's laboratories.

Table 2. Validation of Method 5 Trains with Calibration Orifice No. 144

Meter box	Date	Temperature (° F)	Barometric pressure (in. Hg)	Vacuum (in. Hg)	Velocity head (in. H_2O)	Gas volume at meter (ft^3)	Average meter temperature (° F)	Gas volume meter, normal conditions (m^3)	Gas volume orifice, normal conditions (m^3)	Difference (%)
Nutech #1	8/4/81	69	29.01	14*	1.8	11.478	83.5	0.3075	0.3417	10.0
Nutech #2	7/24/81	72	29.07	14*	1.8	11.307	89	0.3029	0.3424	11.6
2 Nutech	7/10/81	72	26.98	16	1.8	12.585	90.8	0.3096	0.3178	2.6

* The vacuum should be maintained at 17 in. Hg in order to achieve choked flow in the orifice. It is believed that the large difference is due to too low a pump vacuum.

audit orifice and the dry gas meters. On the one run when adequate vacuum was used, good agreement was observed between audit and meter box gas volumes. This audit test is being repeated.

APPENDIX

Field Audit Reports for August 12, 13, and 14, 1981

Quantitative Field Audit

METHOD 5 SAMPLING

Site: Brunner Island

Location: Harrisburg Pa

Date: August 12, 1981

Time:

Auditor(s): Ensor

Nominal Duct Gas Composition _____ CO 12-15% CO_2 5-6% O_2

~~_____ SO_2~~ _____ particulate 3 gr/aft³ Inlet ≈ .008 gr/aft Outlet

_____ gas temperature _____ gas pressure -9.5 in Inlet -14 in Outlet

---

A. GENERAL

1. Operators have access to protocol and test methods?
   yes

2. Data sheets available?
   yes

3. Equipment in good repair?
   yes

B. EQUIPMENT PREPARATION AND CHECK

1. Sampling train assembled and leak checked. yes

2. Probe and filter box heaters checked and set for proper temperatures.
   yes

3. Stack gas temperature measuring system assembled and checked for proper operation by comparing to a mercury-in-glass thermometer.
   No

4. Stack gas velocity measuring system assembled and checked for proper operation. yes

5. Orsat analyzer assembled and checked. yes

C. PRELIMINARY MEASUREMENTS

1. Selection of traverse points according to Method 1.
yes 49 points 7 in 7 ports used

2. Moisture content by Method 4, or equivalent.
~~yes~~ - Previous tests were used

3. Molecular weight by Method 3, or equivalent.
Previous tests were used.

4. Measurement of stack dimensions.
Prints and Plant supplied

5. Mark probe for sampling at traverse points.
yes

6. Diameter of nozzle checked. yes

D. SAMPLE COLLECTION

1. Equal sampling time at each traverse point.
yes

2. Probe temperature satisfactory throughout the test.
yes

3. Filter box temperature 120 ±14° C (248 ±25° F) throughout the test.
yes

4. Sample gas temperature at last impinger 20° C (68° F) throughout the test. Not checked during audit

5. Isokinetic sampling checked and adjusted if necessary at least every 5 minutes. yes

6. Leak check of sampling train at end of test. yes observed at both inlet and outlet

E. SAMPLE RECOVERY

1. Satisfactory handling and movement of probe and filter to sample recovery area. The length of probe required movement to large area of catwalk.

2. Recovery area satisfactory (i.e., space, cleanliness, etc.). Open area with adequate space.

3. Sample recovery procedure adequate. Deionized water wash followed by acetone wash. Three rinses.

4. Proper labeling of sample containers. yes

5. Determination of moisture content procedure adequate. Catch in impinger measured by graduated cylinder. Silica gel to be weighed on platform balance - procedure observed & looked good. Impinger catch was saved.

F. ANALYSIS

1. Proper equilibration of (a) filter, (b) probe wash residue, and (c) acetone blank residue. Not known

2. Correct collected particulate for acetone blank. Not known.

3. Analytical balance checked before weighings. Not known.

G. DOCUMENTATION

1. All information recorded on data sheet as obtained. yes although suggest that time of day should be written on data sheets

2. All unusual conditions recorded. As far as I know

H. COMMENTS

The test I observed had an accident which resulted in a bent probe. This may ~~test~~ tend to cause some doubt on the test eg probe alignment etc.

In general test was well run at both locations

Quantitative Field Audit

METHOD 5 SAMPLING

Site: Brunner Island Station

Location: Harrisburg Pa

Date: Aug. 13, 198[illegible]

Time: 8AM – 4:30 P.M.

Auditor(s): [illegible]

Nominal Duct Gas Composition <0.1% CO 12.7% CO_2 5.4 O_2

- SO_2 - particulate

290°F gas temperature ______ gas pressure

A. GENERAL

1. Operators have access to protocol and test methods? yes

2. Data sheets available? yes

3. Equipment in good repair? yes

B. EQUIPMENT PREPARATION AND CHECK

1. Sampling train assembled and leak checked. yes

2. Probe and filter box heaters checked and set for proper temperatures. yes

3. Stack gas temperature measuring system assembled and checked for proper operation by comparing to a mercury-in-glass thermometer. NO

4. Stack gas velocity measuring system assembled and checked for proper operation. yes

5. Orsat analyzer assembled and checked. yes. Calibrated O_2 cylinder was checked 2-3 times during Method 5 testing. More frequent analysis of O_2 cylinder was recommended.

C. PRELIMINARY MEASUREMENTS

1. Selection of traverse points according to Method 1. yes
There were 49 points in 7 sampling ports

2. Moisture content by Method 4, or equivalent. yes. Method 5 impinger train had impinger with water and silica gel. But the silica gel used was not good when sampling started

3. Molecular weight by Method 3, or equivalent. yes. Orsat was used

4. Measurement of stack dimensions. yes. Prints were supplied by the plant

5. Mark probe for sampling at traverse points. yes

6. Diameter of nozzle checked. yes

D. SAMPLE COLLECTION

1. Equal sampling time at each traverse point. yes

2. Probe temperature satisfactory throughout the test. yes

3. Filter box temperature 120 ±14° C (248 ±25° F) throughout the test. yes

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4. Sample gas temperature at last impinger 20° C (68° F) throughout the test. Yes

5. Isokinetic sampling checked and adjusted if necessary at least every 5 minutes. Yes

6. Leak check of sampling train at end of test. Yes.

E. SAMPLE RECOVERY

1. Satisfactory handling and movement of probe and filter to sample recovery area. Yes. The length of the probe (20 feet) required probe to be moved to a large open area for sample recovery.

2. Recovery area satisfactory (i.e., space, cleanliness, etc.). Yes. The area was satisfactory

3. Sample recovery procedure adequate. Yes. Both water and acetone were used for sample recovery

4. Proper labeling of sample containers. Yes

5. Determination of moisture content procedure adequate. The impinger catch was measured using graduated cylinder. The silica gel used was not good and hence data from the ~~[illegible]~~ sources may not be satisfactory

F. ANALYSIS

1. Proper equilibration of (a) filter, (b) probe wash residue, and (c) acetone blank residue. Not known but talking with ETS personnel it was felt that needed steps will be taken at ETS laboratory.

2. Correct collected particulate for acetone blank. Been informed that ETS will do this at their Lab

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3. Analytical balance checked before weighings. Not known but the ~~attitude~~ The training of the involved people indicates that this will be taken care of

G. DOCUMENTATION

1. All information recorded on data sheet as obtained. yes

2, All unusual conditions recorded. yes

H. COMMENTS Both the inlet and outlet tests were well run. Analysis of calibrated O2 cylinder agreed very well. Field analyzed 5%; Lab analysis = 4.8 to 5.0%. The average outlet orsat data were: CO2 12.9; 5.3%; CO 0.2%

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Quantitative Field Audit

METHOD 5 SAMPLING

Site: Brunner Island

Location: Harrisburg, Pa.

Date: Aug 14, 1981

Time: 8.30 A.M. - 4.00 P.M.

Auditor(s): A D Shendrikar

Nominal Duct Gas Composition 0.1 CO 12.8 CO_2 5.2 O_2

- SO_2 - particulate

[illegible] gas temperature - gas pressure

A. GENERAL

1. Operators have access to protocol and test methods? yes

2. Data sheets available? yes

3. Equipment in good repair? yes

B. EQUIPMENT PREPARATION AND CHECK

1. Sampling train assembled and leak checked. yes

2. Probe and filter box heaters checked and set for proper temperatures. yes

3. Stack gas temperature measuring system assembled and checked for proper operation by comparing to a mercury-in-glass thermometer. NO

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4. Stack gas velocity measuring system assembled and checked for proper operation. yes

5. Orsat analyzer assembled and checked. yes. Calibrated O2 cylinder was analyzed everytime there was a change in the sampling port.

C. PRELIMINARY MEASUREMENTS

1. Selection of traverse points according to Method 1. yes
42 points in 7 ports

2. Moisture content by Method 4, or equivalent. yes But Silica gel used was not good (very few blue crystals were present)

3. Molecular weight by Method 3, or equivalent. yes

4. Measurement of stack dimensions. yes, points were supplied by the plant

5. Mark probe for sampling at traverse points. yes

6. Diameter of nozzle checked. yes

D. SAMPLE COLLECTION

1. Equal sampling time at each traverse point. yes

2. Probe temperature satisfactory throughout the test. yes

3. Filter box temperature 120 ±14° C (248 ±25° F) throughout the test. yes

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4. Sample gas temperature at last impinger 20° C (68° F) throughout the test. yes

5. Isokinetic sampling checked and adjusted if necessary at least every 5 minutes. yes

6. Leak check of sampling train at end of test. yes

E. SAMPLE RECOVERY

1. Satisfactory handling and movement of probe and filter to sample recovery area. yes. The length of probe (25 feet) required it to be moved to a large open area for sample recovery

2. Recovery area satisfactory (i.e., space, cleanliness, etc.). yes The area was satisfactory

3. Sample recovery procedure adequate. yes Both water and acetone were used for sample recovery

4. Proper labeling of sample containers. yes

5. Determination of moisture content procedure adequate. Impinger catches were measured using graduated cylinder. The silica gel used was not good and hence data from the silica may not be satisfactory.

F. ANALYSIS

1. Proper equilibration of (a) filter, (b) probe wash residue, and (c) acetone blank residue. Not known, but talking with ETS personnel it was felt that adequate steps will be taken at ETS Laboratory

2. Correct collected particulate for acetone blank. ETS will do this at their Chemistry Laboratory

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3. Analytical balance checked before weighings. Not known, But the training of the ETS personnel involved indicated that this will be done

G. DOCUMENTATION

1. All information recorded on data sheet as obtained. Yes

2. All unusual conditions recorded. Yes

H. COMMENTS

No problems during testing at both inlet and outlet. Analysis of calibrated O_2 cylinder was carried out 10 times. Data obtained agrees well. Field analyzed 4.7% Lab analysis 4.8 to 5.0%. Average outlet orsat data were: CO_2 12.9%; O_2 5.3%; CO 0.15%.

APPENDIX 8

Cascade Impactor Sampling Results

RESEARCH TRIANGLE INSTITUTE

CASCADE IMPACTOR SAMPLING AT A FABRIC FILTER BAGHOUSE

by

A. S. Viner and D. S. Ensor

Research Triangle Institute
P. O. Box 12191
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Submitted to

ETS, Inc.
3140 Chaparral Drive, S. W.
Roanoke, Virginia 24018

October 1982

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

SECTION 1

INTRODUCTION

Under the EPA project work requirements, impactor tests were carried out during the week of September 1-4, 1982, at Brunner Island Station, owned and operated by the Pennsylvania Power and Light Company. The objective of these tests was to measure size segregated particulate emissions from the fabric filter baghouses. The impactor samples were collected at the inlet and outlet of the baghouses using MRI inertial cascade impactors.

SECTION 2

IMPACTOR SAMPLING

Impactor sampling provides a size segregated sample of particulate matter contained in the flue gas. MRI inertial cascade impactors were used to aerodynamically size segregate the fine particle samples nominally in the diameter range of 0.5 to 10 µm. The impactor design (see Figure 1) is based on a simple annular arrangement of round jets[1] placed in a circular pattern impinging on annular collectors. There are seven impaction stages with a final filter. The use of collection discs permits flexibility in choice of substrate. For example, either a grease or a filter mat can be used to enhance sample collection and its retention on the substrate.

At the Brunner Island Station, stainless steel discs coated with Apiezon-H grease were used to collect fine particle samples from the stack gases. The collection discs have relatively low tare weights and, thus, are ideal for particle sizing sampling since small weight gains due to sample mass can be accurately weighed. Before sampling, impactor collection discs were prepared at the RTI chemistry laboratory. The presampling preparations included individual disc cleaning with a 10-percent solution of nitric acid and rinsing several times in distilled water, followed by a thorough acetone wash. The discs were allowed to dry and coated using a solution of Apiezon-H grease in toluene (1/2 in. length of grease from the tube in 50 ml toluene). The discs were then placed in a tray and heated in an oven at 300° F for four hours. At the end of this period, the discs were removed, cooled, placed in petri dishes, and desiccated for at least 12 hours before presampling weighing. The backup filters (Reeve Angel 934AH) were conditioned with stack gases for two hours in the outlet duct from the baghouse, desiccated for more than 12 hours, and weighed before loading it in the impactor.

Typically, the sampling train consisted of an impactor attached to a probe, followed by a series of impingers placed in an ice bath. The first

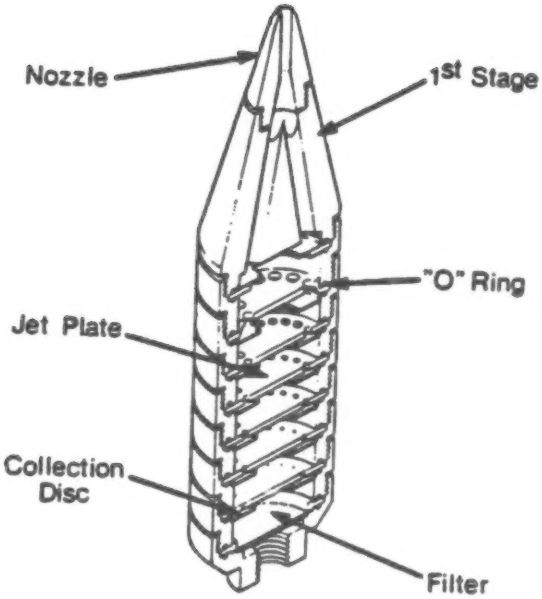
Nozzle
1st Stage
"O" Ring
Jet Plate
Collection Disc
Filter

Figure 1. MRI cascade impactor.

two impingers each contained 250 ml of distilled water. The third impinger was empty and expected to collect carry-over condensables from the flue gas. The fourth impinger had a known weight of silica (approximately 250 g) used for removing moisture from the stack gases and also to protect the pump. The other sampling accessories included pressure and temperature controls and read-outs, a dry gas meter to measure the volume sampled, and a vacuum pump.

The impactor samples were collected by following a procedure similar to that described by Harris.[2] Since there was a large concentration difference (100:1) between inlet and outlet, the outlet impactor tests were conducted for two to four hours to obtain enough sample mass to weigh; however, inlet tests were run for only one to two minutes during the inlet tests. Additionally, at the inlet a comparatively smaller flow rate (0.25 acfm) was used to obtain adequate size sample without overloading the impactor stages. Both inlet and outlet impactor samples were collected at a single point inside the stack.

After the sampling, the impactor was removed from the duct, detached from the probe, and allowed to cool. All samples were recovered inside a clean motel room. The impactor was carefully disassembled and collection discs were placed into petri dishes for protection and storage. Sample material collected on the inside walls of the impactor were brushed onto the appropriate collection stages. All samples were desiccated overnight before determining weight gains using a Perkin-Elmer AD-22 autobalance.

A computer program developed by Denver Research Institute and modified by RTI was used to reduce the size distribution data and generate plots of differential mass distributions and penetrations. Individual data points are not shown since plots show the derivative of an interpolated cumulative size distribution and not the raw data. Particle size distributions are presented as a function of inertial aerodynamic diameter. The particulate collection efficiency of the baghouse is computed by comparison of simultaneous tests at the inlet and outlet. The calculation is made for both total particulate mass and as a function of particle size; the results are expressed as percent penetration. The density of particulate matter was assumed to be 2.5 g/cm^3, a typical value for fly ash. The other parameters needed for impactor data reduction were as follows: water vapor, 7.25 percent; CO_2, 12.50 percent; O_2, 6.0 percent; and CO, 0.0 percent.

SECTION 3

RESULTS AND DISCUSSION

The impactor test series included ten runs: four inlet runs, four outlet runs, and two blank runs. A summary of the results in included in Table 1. One of the blank runs (Run No. 1) had to be discarded because the prefilter was torn, allowing particulate to collect on the impactor substrates.

Inspection of the stage catches for the inlet runs done on 9/2 (Run Nos. 3 and 4) indicated that the sampling time should be increased for subsequent runs. The impactor substrates from the outlet runs on that day (Run Nos. 5 and 6) indicated that some stages were overloaded and the sampling time should be reduced for subsequent runs. The sampling times for Run Nos. 7 through 10 were adjusted accordingly.

The results of the four inlet runs are shown together in Figure 2. The curves all cluster together for particle sizes greater than 1 μm. Some of this variation may be due to variations in the fly ash or reentrainment of dust from the lower stages of the impactor. Nevertheless, the curves show two peaks: one at about 10 μm (aerodynamic diameter), and the other at about 0.4 μm. These results are consistent with the results obtained in previous tests at the Brunner Island Station and at other coal-fired boilers.

The results of the four outlet runs are shown in Figure 3. These curves appear to separate by days over the entire range of particle sizes. This reflects the fact that the outlet grain loading for Run Nos. 9 and 10 was almost twice as high as for the previous runs. The lack of a well defined submicron peak for Run Nos. 5 and 6 may be due to a problem encountered during recovery of the impactor final filter weights (described below).

Table 1. Summary of Brunner Island Tests (1982)

Date/location		MMD (μm)	σ_g
9/2/82	Inlet	20	2.30
	Inlet	21	2.84
9/3/82	Inlet	20	2.35
	Inlet	18.5	1.71
9/2/82	Outlet	9.6	1.92
	Outlet	9.0	1.80
9/3/82	Outlet	9.0	1.96
	Outlet	8.5	1.89
Average inlet		19.9	2.3
Average outlet		9.0	1.9

INLET SIZE DISTRIBUTION

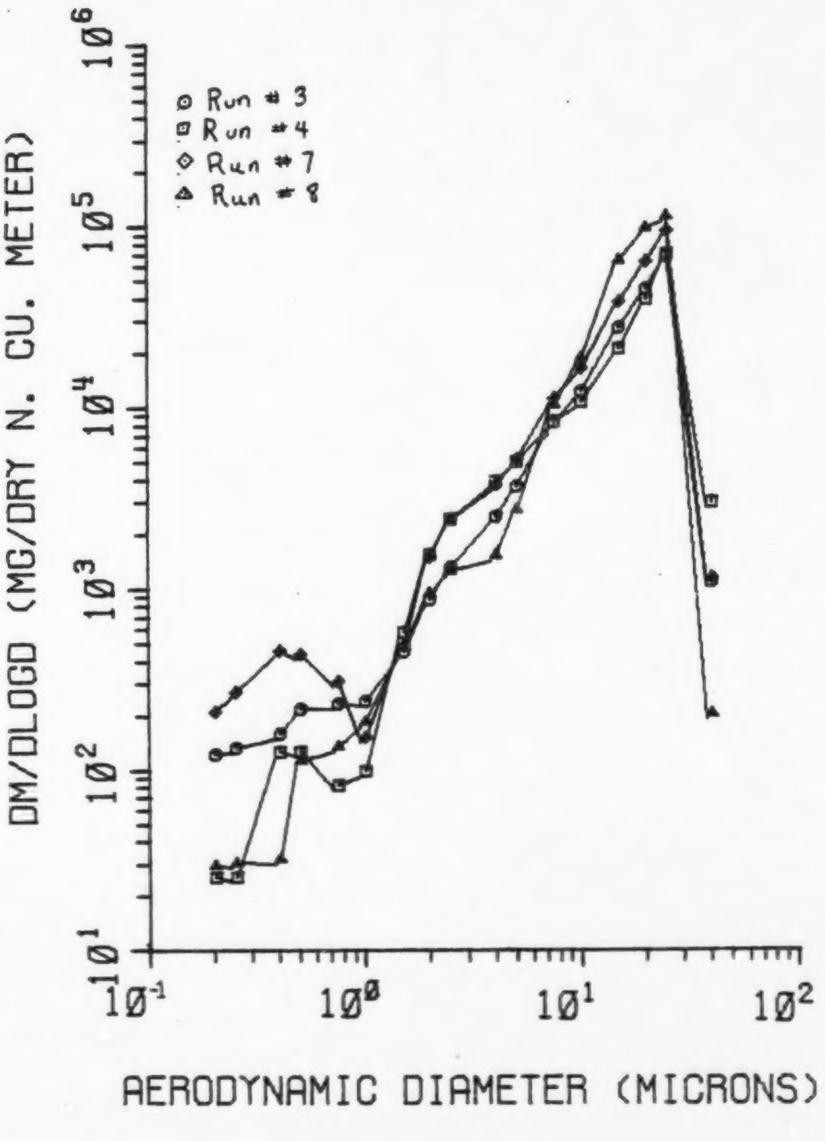

Figure 2.

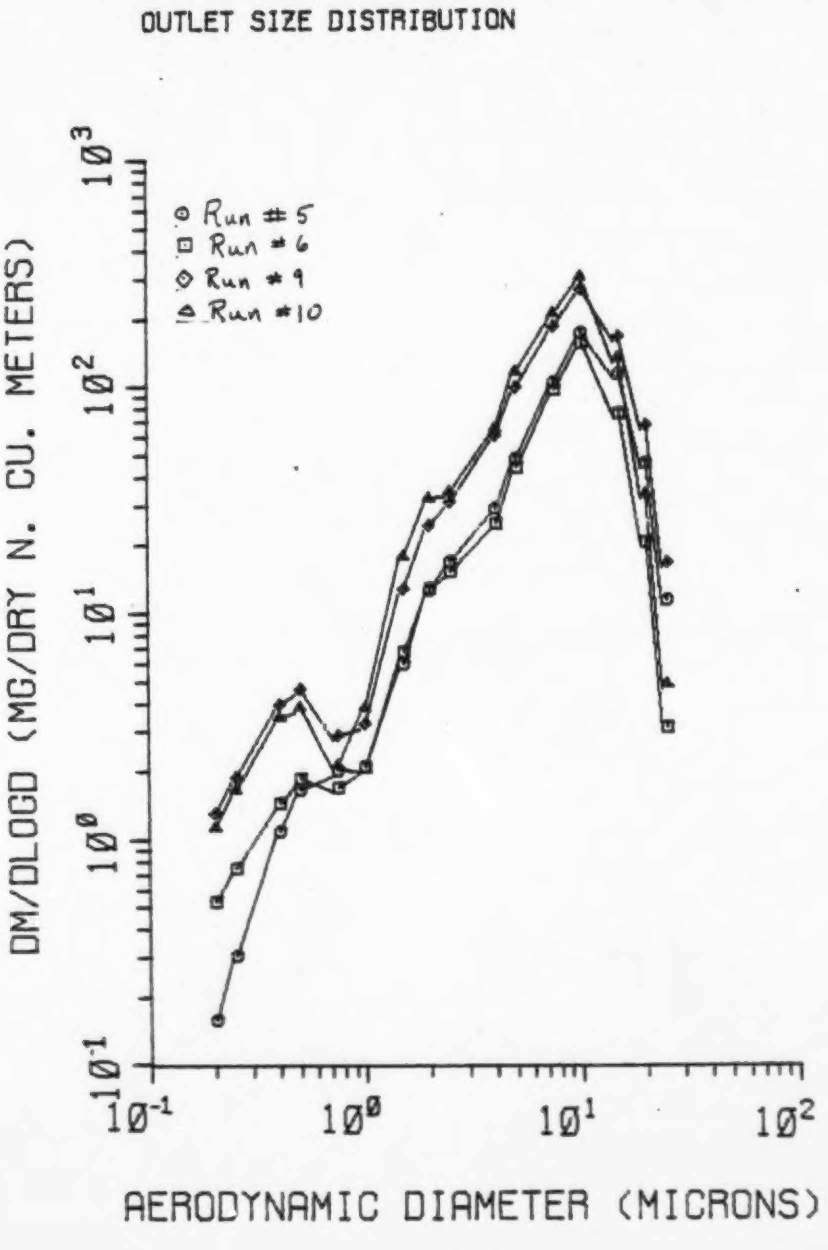
OUTLET SIZE DISTRIBUTION
○ Run # 5
□ Run # 6
◇ Run # 9
△ Run # 10
DM/DLOGD (MG/DRY N. CU. METERS)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-1}
10^{0}
10^{1}
10^{2}
AERODYNAMIC DIAMETER (MICRONS)

Figure 3.

While noting these limitations, it is clear that there are two peaks in the outlet size distribution: One at about 9.0 μm, and the other at 0.4 to 0.5 μm. The upper peak is shifted to the smaller sizes with respect to the corresponding value for the inlet distribution because a baghouse collects large particles most easily. This point is borne out by the penetration curves shown in Figure 4. The vertical spread between the curves reflects the difference between the overall mass penetrations on the two days (1.33 percent on 9/2 versus 1.82 percent on 9/3). The two-day average penetration for each particle size is shown in Figure 5. The trend of increasing penetration with particle size in the 1.0 to 10.0 μm range has been observed in other baghouses (Ensor et al., 1981) and may be due to seepage through the bags. The penetrations curves are consistent with the high outlet grain loadings observed in this test series when compared to the field test of August 1981.

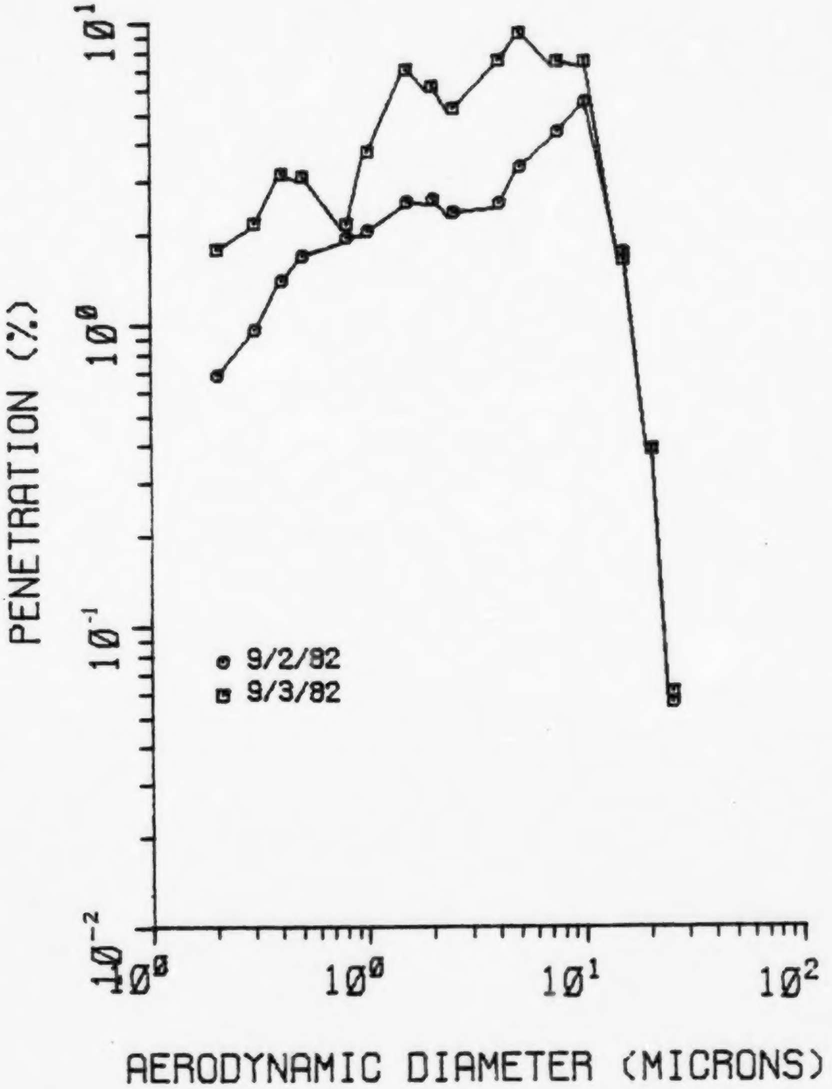
PENETRATION (%)
10^1
10^0
10^-1
10^-2
10^0
10^0
10^1
10^2
AERODYNAMIC DIAMETER (MICRONS)
9/2/82
9/3/82

Figure 4.

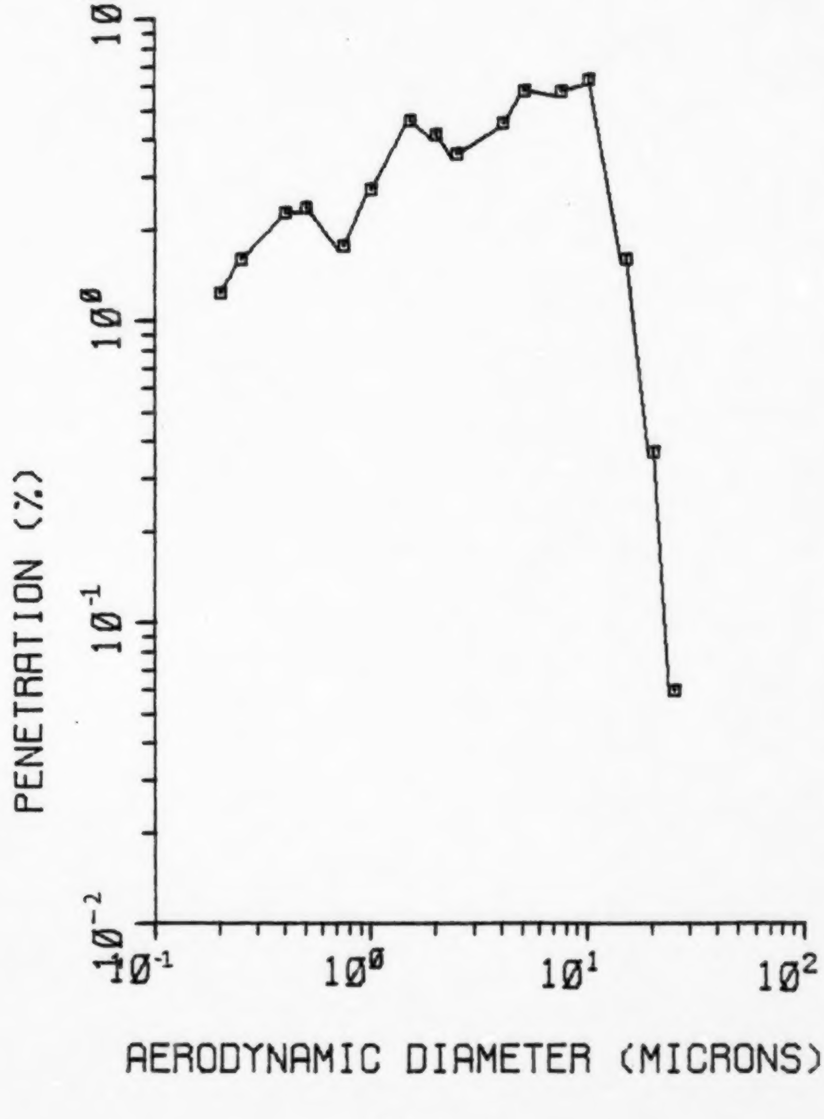
10^1
10^0
10^-1
10^-2
PENETRATION (%)
10^-1
10^0
10^1
10^2
AERODYNAMIC DIAMETER (MICRONS)

Figure 5.

SECTION 4

DATA QUALITY

Quality assurance efforts related to fine particle sampling emphasized substrate preparation, sampling, and sample recovery techniques, and weighing operations. The substrates were prepared at RTI's home laboratory, weighed on two balances (a Perkin-Elmer AD-22 autobalance and a Metler balance), sealed and transported to the test site. Prior to a day of sampling, the required number of substrates were desiccated for at least 12 hours. A standard substrate and substrates for sampling were weighed before loading into the impactor. The loaded impactor was sealed and carried to the testing site. After sampling, the samples were recovered in a clean room at a motel and desiccated overnight before weighing. Both the test runs were checked for constant weight over a period of two days. An NBS-traceable weight was used to calibrate the balance and, also, to evaluate the performance of the balance during sample weighing operations.

Two blank runs were conducted during the test series: one at the inlet, and one at the outlet. The prefilter on the outlet blank run was torn, allowing particulate to collect on the impactor substrates. This run was discarded. The inlet blank run showed an average weight gain of 0.33 mg with a standard deviation of 0.09.

All of the impactor substrate weights were measured with great precision (0.02 mg), and the stage weight gains share this precision. A problem was encountered when weighing the impactor final filters. Because of the use of an aluminum cup for holding the filter during weighing, the tare weights were typically close to the maximum weight limit of the balance. The balance was not able to give a stable reading at these conditions, but it was believed that the preweights were accurate to within 0.05 mg. Upon recovery of the filters after each run, however, the postweights were all significantly lower than the preweights, although mass was readily visible on the filters. To determine the weight gain on the filters, the weights of 11 clean conditioned filters were measured (without aluminum cups). The average of these weights was used as an estimated preweight for all of the impactor final filters. The final filters were weighed, and the weight gain was calculated by subtracting the estimated preweight from the postweight. In spite of the limitations of this method, the heavy grain loadings encountered produced large filter catches. The weight gain was easy to infer by this method, and all filter catches were found to be positive. The uncertainty in the final filter weight will only affect the mass distribution for particles less than 0.5 um and, thus, does not contribute significantly to the overall mass penetrations.

REFERENCES

1. Cohen, J. J., and D. M. Montan. Theoretical Considerations, Design, and Evaluation of a Cascade Impactor. Am. Ind. Hyg. Assoc. J., 28:95, 1967.

2. Harris, D. B. Tentative Procedures for Particle Sizing in Process Streams: Cascade Impactors. EPA-600/2-76-023, U. S. Environmental Protection Agency, 1976.

3. Ensor, D. S., S. Cowen, A. D. Shendrikar, G. Markowski, and G. Woffinden. Kramer Station Fabric Filter Evaluation. EPRI Report No. 1130-1, Electric Power Research Institute, Palo Alto, California, 1981.

4. Markowski, G. R., D. S. Ensor, R. G. Hooper, and R. C. Carr. A Submicron Aerosol Mode in Flue Gas from a Pulverized Coal Utility Boiler. EST, 14:1400-1402, 1980.

APPENDIX 9

Coal Analysis

REPORT OF ANALYSIS

Lab No. 166914
Sample of Coal
PR&L Brunnen - 9/2/82
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	4.66%	----%
Volatile Matter	23.91%	25.08%
Ash	12.95%	13.58%
Sulphur	2.15%	2.26%
Heating Value, Btu	12,647	13,265
Free Swelling Index, ASTM	8	

REPORT OF ANALYSIS

Lab No. 166915
Sample of Coal
PR&L Brunnen - 9/3/82
From ETS, Inc., Roanoke, VA

	As Rec'd.	Dry Coal
Moisture	5.66%	-----%
Volatile Matter	20.91%	22.16%
Ash	10.92%	11.57%
Sulphur	2.28%	2.42%
Heating Value, Btu	13,076	13,861
Free Swelling Index, ASTM	8 1/2	

APPENDIX 10

Computer Printouts

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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PP&L-BRUNNER ISLAND STATION

PLANT LOCATION  HARRISBURG,PA.

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  UNIT 1 INLET-RUN 1

POLLUTANTS      PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         09/02/82
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ETS, INC.-ISOKINETIC SAMPLING ANALYSIS 09/02/82 PAGE 1

POINT            CLOCK    TIME    STACK            STACK            VELOCITY
NO.              TIME    INCRMT   PRESS            TEMP             HEAD
                 (MINS.)          (IN.H2O)         (F)              (IN.H2O)
A1                1312      0     -9.5              314.8            .908
G7                1628      196   -9.5              314.8            .908

                          TT      PS               TS               DPS
OVERALL                   196     -9.5              314.8           .91
RESULT                    (NET)   (AVG)            (AVG)            (AVG)

POINT            ORIFICE          DRY GS           GAS TEMP.        STACK
NO.              DELTA H          METER            IN OUT           GAS VEL
                 (IN.H2O)         (CF)             (DEGREES F)      AFPM
A1               0.35              9.6              93.8    93.8    3966.3
G7               0.35              72.54            93.8    93.8    3966.3

                 DH               VMN              TM
                 0.35             62.940           93.8             3966.3
                 (AVG)            (NET)            (AVG)            (AVG)
```

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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 09/02/82 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      INLET RUN 1
DATE OF RUN                                     09/02/82
TIME AT BEGINNING OF RUN                         1312
TIME AT END OF RUN                               1628
DN              SAMPLING NOZZLE DIAMETER         .15 IN.
PBAR            BAROMETRIC PRESSURE              29.36 IN.HG.ABS.
TT              NET TIME OF TEST                 196 MIN.
VMN             SAMPLE GAS VOLUME                62.94 CU.FT.
TM              AVG.GAS METER TEMPERATURE       93.8 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       0.35 IN.H20
VMSTD           VOLUME OF DRY GAS SAMPLED       59.146 DSCF


VLC             H20 FM IMPING. SILICA GEL        154 ML
VWSTD           H20 COLLECTED AT STD.COND.        7.300 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.       11.0 PERCENT
                CO2 IN DRY STACK GASES           13.0 PERCENT
                O2 IN DRY STACK GASES             6.0 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.0 PERCENT
MFDG            MOL FRACTION OF DRY GAS           0.89
EA              EXCESS AIR                       39.00 PERCENT
MS              MOL WGT OF STACK GAS,WET         28.97


SA              STACK AREA                       41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -0.70 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 28.66 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             314.8 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     3966 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %666215 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1142240 ACFM


I               ISOKINETIC RATIO                106.0 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  09/02/82 PAGE 3


NOZZLE AND THIMBLE                GRAMS             0.0000
                                  GRAINS/ACF        0.0000
                                  GRAINS/SCF        0.0000
                                  LB/HR-CONC        0.00
                                  LB/HR-AREA        0.00
                                  LB/HR-AVG         0.00


PROBE                             GRAMS             0.1730
TOTAL-ABOVE ITEMS                 GRAMS             0.1730
                                  GRAINS/ACF        0.0263
                                  GRAINS/SCF        0.0451
                                  LB/HR-CONC       %257.24
                                  LB/HR-AREA       %273.69
                                  LB/HR-AVG        %265.46


FILTER                            GRAMS            11.5144
TOTAL-ABOVE ITEMS                 GRAMS            11.6874
                                  GRAINS/ACF        1.7746
                                  GRAINS/SCF        3.0431
                                  LB/HR-CONC       %17374.30
                                  LB/HR-AREA       %18485.40
                                  LB/HR-AVG        %17929.80


TOTAL-INCL.IMPINGER CATCH       GRAMS             11.6874
                                  GRAINS/ACF        1.7746
                                  GRAINS/SCF        3.0431
                                  LB/HR-CONC       %17374.30
                                  LB/HR-AREA       %18485.40
                                  LB/HR-AVG        %17929.80
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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PP&L-BRUNNER ISLAND STATION

PLANT LOCATION  HARRISBURG,PA.

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  UNIT 1 INLET-RUN 2

POLLUTANTS      PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         09/03/82
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ETS, INC.-ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 1

POINT     CLOCK    TIME STACK     STACK     VELOCITY
NO.       TIME   INCRMT PRESS     TEMP      HEAD
          (MINS.)       (IN.H20)  (F)       (IN.H20)
A1         857     0    -9.5       308.4     1.06
G7         1213     196 -9.5       308.4     1.06

                TT  PS        TS        DPS
OVERALL         196 -9.5       308.4    %1.06
RESULT          (NET) (AVG)   (AVG)     (AVG)


POINT     ORIFICE   DRY GS    GAS TEMP. STACK
NO.       DELTA H   METER     IN OUT    GAS VEL
          (IN.H20)  (CF)      (DEGREES F) AFPM
A1        0.43       76.87     74.8   74.8  4274.0
G7        0.43       138.1     74.8   74.8  4274.0

          DH        VMN       TM
          0.43      61.230    74.8      4274.0
          (AVG)     (NET)     (AVG)     (AVG)
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      INLET RUN 2
DATE OF RUN                                     09/03/82
TIME AT BEGINNING OF RUN                         857
TIME AT END OF RUN                               1213
DN              SAMPLING NOZZLE DIAMETER         .15 IN.
PBAR            BAROMETRIC PRESSURE              29.32 IN.HG.ABS.
TT              NET TIME OF TEST                 196 MIN.
VMN             SAMPLE GAS VOLUME                61.23 CU.FT.
TM              AVG.GAS METER TEMPERATURE       74.8 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       0.43 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       59.515 DSCF


VLC             H2O FM IMPING. SILICA GEL        157 ML
VWSTD           H2O COLLECTED AT STD.COND.        7.442 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.       11.1 PERCENT
                CO2 IN DRY STACK GASES           12.8 PERCENT
                O2 IN DRY STACK GASES             6.0 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.2 PERCENT
MFDG            MOL FRACTION OF DRY GAS           0.89
EA              EXCESS AIR                       38.87 PERCENT
MS              MOL WGT OF STACK GAS,WET         28.92


SA              STACK AREA                       41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -0.70 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 28.62 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             308.4 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     4274 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %721816 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1230840 ACFM


I               ISOKINETIC RATIO                 98.4 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  09/03/82 PAGE 3


NOZZLE AND THIMBLE              GRAMS            0.0000
                                GRAINS/ACF       0.0000
                                GRAINS/SCF       0.0000
                                LB/HR-CONC       0.00
                                LB/HR-AREA       0.00
                                LB/HR-AVG        0.00

PROBE                           GRAMS            0.3755
TOTAL-ABOVE ITEMS               GRAMS            0.3755
                                GRAINS/ACF       0.0570
                                GRAINS/SCF       0.0972
                                LB/HR-CONC      %601.07
                                LB/HR-AREA      %593.92
                                LB/HR-AVG       %597.50

FILTER                          GRAMS           15.1069
TOTAL-ABOVE ITEMS               GRAMS           15.4824
                                GRAINS/ACF       2.3490
                                GRAINS/SCF       4.0062
                                LB/HR-CONC      %24782.40
                                LB/HR-AREA      %24487.70
                                LB/HR-AVG       %24635.00

TOTAL-INCL.IMPINGER CATCH     GRAMS           15.4824
                                GRAINS/ACF       2.3490
                                GRAINS/SCF       4.0062
                                LB/HR-CONC      %24782.40
                                LB/HR-AREA      %24487.70
                                LB/HR-AVG       %24635.00
```

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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PP&L-BRUNNER ISLAND STATION

PLANT LOCATION  HARRISBURG,PA.

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  UNIT 1 INLET-RUN 3

POLLUTANTS      PARTICULATE EMISSIONS

                        ETS, INC.

                        ROANOKE, VIRGINIA

                        09/03/82
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ETS, INC.-ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 1

POINT           CLOCK   TIME    STACK           STACK           VELOCITY
NO.             TIME   INCRMT   PRESS           TEMP            HEAD
                (MINS.)         (IN.H20)        (F)             (IN.H20)
A1               1330     0     -9.5             313.6           .95
G7               1558     147   -9.5             313.6           .95

                         TT     PS              TS              DPS
OVERALL                  147    -9.5             313.6          .95
RESULT                  (NET)   (AVG)           (AVG)           (AVG)

POINT           ORIFICE         DRY GS          GAS TEMP.       STACK
NO.             DELTA H         METER           IN OUT          GAS VEL
                (IN.H20)        (CF)            (DEGREES F)     AFPM
A1              1.65             140.6           82.2   82.2    4042.5
G7              1.65             228.44          82.2   82.2    4042.5

                DH              VMN             TM
                1.65            87.840          82.2            4042.5
                (AVG)           (NET)           (AVG)           (AVG)
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      INLET RUN 3
DATE OF RUN                                     09/03/82
TIME AT BEGINNING OF RUN                         1330
TIME AT END OF RUN                               1558
DN              SAMPLING NOZZLE DIAMETER         .219 IN.
PBAR            BAROMETRIC PRESSURE             29.36 IN.HG.ABS.
TT              NET TIME OF TEST                 147 MIN.
VMN             SAMPLE GAS VOLUME                87.84 CU.FT.
TM              AVG.GAS METER TEMPERATURE       82.2 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       1.65 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       84.586 DSCF


VLC             H2O FM IMPING. SILICA GEL        180 ML
VWSTD           H2O COLLECTED AT STD.COND.        8.532 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.        9.2 PERCENT
                CO2 IN DRY STACK GASES           12.5 PERCENT
                O2 IN DRY STACK GASES             6.3 PERCENT
                CO IN DRY STACK GASES             0.0 PERCENT
                N2 IN DRY STACK GASES            81.2 PERCENT
MFDG            MOL FRACTION OF DRY GAS          0.91
EA              EXCESS AIR                       41.62 PERCENT
MS              MOL WGT OF STACK GAS,WET         29.13


SA              STACK AREA                       41472 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -0.70 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 28.66 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             313.6 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     4043 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %693997 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1164180 ACFM


I               ISOKINETIC RATIO                 91.0 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  09/03/82 PAGE 3


NOZZLE AND THIMBLE               GRAMS             0.0000
                                 GRAINS/ACF        0.0000
                                 GRAINS/SCF        0.0000
                                 LB/HR-CONC        0.00
                                 LB/HR-AREA        0.00
                                 LB/HR-AVG         0.00


PROBE                            GRAMS             0.1134
TOTAL-ABOVE ITEMS                GRAMS             0.1134
                                 GRAINS/ACF        0.0123
                                 GRAINS/SCF        0.0207
                                 LB/HR-CONC       %122.83
                                 LB/HR-AREA       %112.22
                                 LB/HR-AVG        %117.52


FILTER                           GRAMS            22.2450
TOTAL-ABOVE ITEMS                GRAMS            22.3584
                                 GRAINS/ACF        2.4262
                                 GRAINS/SCF        4.0706
                                 LB/HR-CONC       %24210.40
                                 LB/HR-AREA       %22119.90
                                 LB/HR-AVG        %23165.10


TOTAL-INCL.IMPINGER CATCH      GRAMS            22.3584
                                 GRAINS/ACF        2.4262
                                 GRAINS/SCF        4.0706
                                 LB/HR-CONC       %24210.40
                                 LB/HR-AREA       %22119.90
                                 LB/HR-AVG        %23165.10
```

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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PP&L-BRUNNER ISLAND

PLANT LOCATION  HARRISBURG,PA.

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  UNIT 1 OUTLET-RUN 1

POLLUTANTS      PARTICULATE EMISSIONS

                          ETS, INC.

                          ROANOKE, VIRGINIA

                          09/02/82
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ETS, INC.-ISOKINETIC SAMPLING ANALYSIS 09/02/82 PAGE 1

POINT     CLOCK    TIME   STACK       STACK       VELOCITY
NO.       TIME    INCRMT  PRESS       TEMP        HEAD
          (MINS.)         (IN.H2O)    (F)         (IN.H2O)
A1         1312     0     -19.5        318         .669
G7         1608      176  -19.5        318         .669

               TT         PS          TS          DPS
OVERALL        176        -19.5        318        .67
RESULT         (NET)      (AVG)       (AVG)       (AVG)

POINT     ORIFICE         DRY GS      GAS TEMP.   STACK
NO.       DELTA H         METER       IN OUT      GAS VEL
          (IN.H2O)        (CF)        (DEGREES F) AFPM
A1        1.58             823.145     89.7   89.7 3413.8
G7        1.58             945.29      89.7   89.7 3413.8

          DH              VMN         TM
          1.58            %122.145    89.7        3413.8
          (AVG)           (NET)       (AVG)       (AVG)
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 09/02/82 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                        RUN 1 OUTLET
DATE OF RUN                                       09/02/82
TIME AT BEGINNING OF RUN                           1312
TIME AT END OF RUN                                 1608
DN              SAMPLING NOZZLE DIAMETER           .24 IN.
PBAR            BAROMETRIC PRESSURE                29.36 IN.HG.ABS.
TT              NET TIME OF TEST                   176 MIN.
VMN             SAMPLE GAS VOLUME                  122.145 CU.FT.
TM              AVG.GAS METER TEMPERATURE         89.7 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP         1.58 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED         %115.994 DSCF


VLC             H2O FM IMPING. SILICA GEL          132 ML
VWSTD           H2O COLLECTED AT STD.COND.          6.257 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.          5.1 PERCENT
                CO2 IN DRY STACK GASES             13.0 PERCENT
                O2 IN DRY STACK GASES               6.0 PERCENT
                CO IN DRY STACK GASES               0.0 PERCENT
                N2 IN DRY STACK GASES              81.0 PERCENT
MFDG            MOL FRACTION OF DRY GAS             0.95
EA              EXCESS AIR                         39.00 PERCENT
MS              MOL WGT OF STACK GAS,WET           29.69


SA              STACK AREA                         57600 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS         -1 IN.HG.ABS.
PSA             STACK GAS PRESSURE                   27.93 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE               318.0 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.       3414 AFPM
QS              STACK GAS VOL.,DRY STD.COND.      %823731 DSCFM
QA              STACK GAS VOLUME,STACK COND.      %1365460 ACFM


I               ISOKINETIC RATIO                  101.6 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  09/02/82 PAGE 3


NOZZLE AND THIMBLE              GRAMS             0.0000
                                GRAINS/ACF        0.0000
                                GRAINS/SCF        0.0000
                                LB/HR-CONC        0.00
                                LB/HR-AREA        0.00
                                -AVG         0.00

PROBE                           GRAMS             0.1740
TOTAL-ABOVE ITEMS               GRAMS             0.1740
                                GRAINS/ACF        0.0139
                                GRAINS/SCF        0.0231
                                LB/HR-CONC       %163.10
                                LB/HR-AREA       %166.29
                                LB/HR-AVG        %164.70

FILTER                          GRAMS             0.0935
TOTAL-ABOVE ITEMS               GRAMS             0.2675
                                GRAINS/ACF        0.0214
                                GRAINS/SCF        0.0355
                                LB/HR-CONC       %250.73
                                LB/HR-AREA       %255.64
                                LB/HR-AVG        %253.19

TOTAL-INCL.IMPINGER CATCH     GRAMS             0.2675
                                GRAINS/ACF        0.0214
                                GRAINS/SCF        0.0355
                                LB/HR-CONC       %250.73
                                LB/HR-AREA       %255.64
                                LB/HR-AVG        %253.19
```

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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME     PP&L-BRUNNER ISLAND

PLANT LOCATION  HARRISBURG,PA.

PROCESS         COAL-FIRED BOILER

CONTROL EQUIPMT BAGHOUSE

SAMPLING POINT  UNIT 1 OUTLET-RUN 2

POLLUTANTS      PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         09/03/82
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ETS, INC.-ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 1

POINT     CLOCK TIME     STACK     STACK     VELOCITY
NO.       TIME INCRMT    PRESS     TEMP      HEAD
          (MINS.)        (IN.H2O)  (F)       (IN.H2O)
A1         857    0      -19.5      306       .76
G7         1213    196   -19.5      306       .76

                TT       PS        TS        DPS
OVERALL         196      -19.5      306      .76
RESULT          (NET)    (AVG)     (AVG)     (AVG)


POINT     ORIFICE        DRY GS    GAS TEMP.     STACK
NO.       DELTA H        METER     IN OUT        GAS VEL
          (IN.H2O)       (CF)      (DEGREES F)   AFPM
A1        1.81            945.23    77.5   77.5  3609.2
G7        1.81            1093.17   77.5   77.5  3609.2

          DH             VMN       TM
          1.81           %147.936  77.5          3609.2
          (AVG)          (NET)     (AVG)         (AVG)
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 2
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RUN NUMBER                                            RUN 2 OUTLET
DATE OF RUN                                           09/03/82
TIME AT BEGINNING OF RUN                               857
TIME AT END OF RUN                                     1213
DN               SAMPLING NOZZLE DIAMETER              .24 IN.
PBAR             BAROMETRIC PRESSURE                   29.32 IN.HG.ABS.
TT               NET TIME OF TEST                      196 MIN.
VMN              SAMPLE GAS VOLUME                     147.936 CU.FT.
TM               AVG.GAS METER TEMPERATURE            77.5 DEGR.F.
DH               AVG. ORIFICE PRESSURE DROP            1.81 IN.H2O
VMSTD            VOLUME OF DRY GAS SAMPLED            %143.564 DSCF


VLC              H20 FM IMPING. SILICA GEL             132 ML
VWSTD            H20 COLLECTED AT STD.COND.             6.257 STD.CU.FT.
BWS              STACK GAS MOISTURE BY VOL.             4.2 PERCENT
                 CO2 IN DRY STACK GASES               12.6 PERCENT
                 O2 IN DRY STACK GASES                  6.2 PERCENT
                 CO IN DRY STACK GASES                  0.0 PERCENT
                 N2 IN DRY STACK GASES                81.2 PERCENT
MFDG             MOL FRACTION OF DRY GAS               0.96
EA               EXCESS AIR                           40.69 PERCENT
MS               MOL WGT OF STACK GAS,WET              29.75


SA               STACK AREA                            57600 SQ.IN.
P2               STATIC PRESSURE OF STACK GAS            -1.43 IN.HG.ABS.
PSA              STACK GAS PRESSURE                      27.89 IN.HG.ABS.
TS               AVG.STACK TEMPERATURE                  306.0 DEGR.F.
VS               STACK GAS VELOC.,STACK COND.          3609 AFPM
QS               STACK GAS VOL.,DRY STD.COND.         %892025 DSCFM
QA               STACK GAS VOLUME,STACK COND.         %1443620 ACFM


I                ISOKINETIC RATIO                     104.2 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  09/03/82 PAGE 3


NOZZLE AND THIMBLE              GRAMS           0.0000
                                GRAINS/ACF      0.0000
                                GRAINS/SCF      0.0000
                                LB/HR-CONC      0.00
                                LB/HR-AREA      0.00
                                LB/HR-AVG       0.00

PROBE                           GRAMS           0.3229
TOTAL-ABOVE ITEMS               GRAMS           0.3229
                                GRAINS/ACF      0.0214
                                GRAINS/SCF      0.0346
                                LB/HR-CONC     %264.77
                                LB/HR-AREA     %277.06
                                LB/HR-AVG      %270.92

FILTER                          GRAMS           0.1589
TOTAL-ABOVE ITEMS               GRAMS           0.4818
                                GRAINS/ACF      0.0319
                                GRAINS/SCF      0.0517
                                LB/HR-CONC     %395.05
                                LB/HR-AREA     %413.39
                                LB/HR-AVG      %404.22

TOTAL-INCL.IMPINGER CATCH     GRAMS            0.4818
                                GRAINS/ACF      0.0319
                                GRAINS/SCF      0.0517
                                LB/HR-CONC     %395.05
                                LB/HR-AREA     %413.39
                                LB/HR-AVG      %404.22
```

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SOURCE ISOKINETIC SAMPLING ANALYSIS

PROGRAM METH5

CLIENT NAME      PP&L-BRUNNER ISLAND

PLANT LOCATION   HARRISBURG,PA.

PROCESS          COAL-FIRED BOILER

CONTROL EQUIPMT  BAGHOUSE

SAMPLING POINT   UNIT 1 OUTLET-RUN 3

POLLUTANTS       PARTICULATE EMISSIONS

                         ETS, INC.

                         ROANOKE, VIRGINIA

                         09/03/82
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ETS, INC.-ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 1

POINT            CLOCK   TIME    STACK          STACK          VELOCITY
NO.              TIME   INCRMT   PRESS          TEMP           HEAD
                 (MINS.)         (IN.H2O)       (F)            (IN.H2O)
A1                1330     0     -19.5           311             .65
G7                1558    148    -19.5           311             .65

                          TT     PS             TS             DPS
OVERALL                  148     -19.5           311           .65
RESULT                   (NET)   (AVG)          (AVG)          (AVG)

POINT            ORIFICE         DRY GS         GAS TEMP.      STACK
NO.              DELTA H         METER          IN OUT         GAS VEL
                 (IN.H2O)        (CF)           (DEGREES F)    AFPM
A1               1.54             95.286         86    86      3351.3
G7               1.54             198.806        86    86      3351.3

                 DH              VMN            TM
                 1.54            %103.520       86.0           3351.3
                 (AVG)           (NET)          (AVG)          (AVG)
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ETS,INC.--ISOKINETIC SAMPLING ANALYSIS 09/03/82 PAGE 2

RESULT OF FLOWS AND ISOKINETIC CALCULATIONS-

RUN NUMBER                                      RUN 3 OUTLET
DATE OF RUN                                     09/03/82
TIME AT BEGINNING OF RUN                         1330
TIME AT END OF RUN                               1558
DN              SAMPLING NOZZLE DIAMETER         .24 IN.
PBAR            BAROMETRIC PRESSURE              29.36 IN.HG.ABS.
TT              NET TIME OF TEST                 148 MIN.
VMN             SAMPLE GAS VOLUME                103.52 CU.FT.
TM              AVG.GAS METER TEMPERATURE       86.0 DEGR.F.
DH              AVG. ORIFICE PRESSURE DROP       1.54 IN.H2O
VMSTD           VOLUME OF DRY GAS SAMPLED       98.964 DSCF


VLC             H2O FM IMPING. SILICA GEL        106 ML
VWSTD           H2O COLLECTED AT STD.COND.        5.024 STD.CU.FT.
BWS             STACK GAS MOISTURE BY VOL.        4.8 PERCENT
                CO2 IN DRY STACK GASES          12.5 PERCENT
                O2 IN DRY STACK GASES            6.4 PERCENT
                CO IN DRY STACK GASES            0.0 PERCENT
                N2 IN DRY STACK GASES           81.1 PERCENT
MFDG            MOL FRACTION OF DRY GAS          0.95
EA              EXCESS AIR                      42.64 PERCENT
MS              MOL WGT OF STACK GAS,WET         29.66


SA              STACK AREA                       57600 SQ.IN.
P2              STATIC PRESSURE OF STACK GAS       -1.43 IN.HG.ABS.
PSA             STACK GAS PRESSURE                 27.93 IN.HG.ABS.
TS              AVG.STACK TEMPERATURE             311.0 DEGR.F.
VS              STACK GAS VELOC.,STACK COND.     3351 AFPM
QS              STACK GAS VOL.,DRY STD.COND.    %818441 DSCFM
QA              STACK GAS VOLUME,STACK COND.    %1340440 ACFM


I               ISOKINETIC RATIO                103.7 PERCENT
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ETS,INC.-ISOKINETIC SAMPLING ANALYSIS  09/03/82 PAGE 3


NOZZLE AND THIMBLE               GRAMS             0.0000
                                 GRAINS/ACF        0.0000
                                 GRAINS/SCF        0.0000
                                 LB/HR-CONC        0.00
                                 LB/HR-AREA        0.00
                                 LB/HR-AVG         0.00

PROBE                            GRAMS             0.2479
TOTAL-ABOVE ITEMS                GRAMS             0.2479
                                 GRAINS/ACF        0.0235
                                 GRAINS/SCF        0.0386
                                 LB/HR-CONC      %270.57
                                 LB/HR-AREA      %281.70
                                 LB/HR-AVG       %276.13

FILTER                           GRAMS             0.1157
TOTAL-ABOVE ITEMS                GRAMS             0.3636
                                 GRAINS/ACF        0.0345
                                 GRAINS/SCF        0.0566
                                 LB/HR-CONC      %396.85
                                 LB/HR-AREA      %413.18
                                 LB/HR-AVG       %405.02

TOTAL-INCL.IMPINGER CATCH      GRAMS             0.3636
                                 GRAINS/ACF        0.0345
                                 GRAINS/SCF        0.0566
                                 LB/HR-CONC      %396.85
                                 LB/HR-AREA      %413.18
                                 LB/HR-AVG       %405.02
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APPENDIX 11

Quality Assurance Report

QUALITY CONTROL SUMMARY

Brunner Island Station

September 2, 1982

Observation of the Method 5 Testing

The Method 5 tests at both inlet and outlet were observed by Dr. David S. Ensor. The following conclusions were drawn:

1. The testing was conducted properly and in accordance with the EPA Method 5.
2. The sample recovery was adequate.

Tests with Critical Orifice

The orifice test is intended to determine the accuracy of the Method 5 gas metering equipment. A calibrated orifice (No. 329) is attached to the inlet of the meter, a vacuum of at least 19 in. Hg is maintained at the pump, and ambient air is drawn through the orifice for a measured time.

	Outlet box	Inlet box
Date	9/2/82	9/2/82
Time of day	12:50 p.m.	12:40 p.m.
Barometric pressure, in. Hg	29.32	29.32
Ambient temperature, ° F	80	79
Meter volume, ft^3	4.294	4.523
Vacuum, in. Hg	21.75	21.50
ΔH, in. H_2O	1.8	2.1
Elapsed time, min	6	6
Volume (meter box), m^2 at 20° C 750 mm Hg	0.11699	0.12274
Volume (orifice), m^2 at 20° C 760 mm hg	0.114499	0.12113
Difference, %	2.18	1.33

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